

**RESPONSE OF WILD MAMMALIAN SPECIES TO  
HUMAN-MEDIATED RESOURCE BASE IN CHAMOLI  
DISTRICT OF UTTARAKHAND, INDIA**

**Dissertation submitted to Saurashtra University, Rajkot  
in Partial Fulfilment of the Masters of Science Degree  
in Wildlife Science**

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## CERTIFICATE

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This is to certify that **Ms. Nimisha Srivastava** student of Wildlife Institute of India has carried out an original research titled “**Response of mammals to human mediated resource base in Chamoli district of Uttarakhand, India**” in partial fulfilment of her “**Masters in Wildlife Science**” from **Saurashtra University**, Rajkot. This study was carried out under our supervision at the **Wildlife Institute of India** from December 2016 to June 2017. We also certify that this work has not been submitted for any other degree to any other university.

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## ABSTRACT

1. Increasing human population and continuous alteration in land-use patterns for different purposes are affecting ecosystems across the globe and one of the outcomes is human modified landscapes (HML), where human and wildlife continue to interact either explicitly or implicitly. These spaces are also source of habitat and forage for certain species that are successful in adapting to these changes and exploiting the opportunities available here, while causing conflicts when threshold of interaction is crossed. Therefore, conservation efforts are required in these areas in order to ensure functional co-existence and to integrate human modified landscapes in the larger conservation management strategies. With just a handful of studies focusing on conservation outside protected areas, this study focuses on the wild animals that occur in human-modified landscapes, in line with the proposed national strategy to manage wildlife in such landscapes. With the aim of focusing on the factors that drive or facilitate species to thrive in human modified areas, I carried out an investigation on the ‘response of wild animals to human modified landscape in Mandal Sub-basin (ca 140 km<sup>2</sup>), Chamoli district, Uttarakhand’ from December 2016 to April 2017.

2. For the study, I assessed distribution and use of various land use types (human inhabitations, crop fields, secondary scrub around villages, moist and dry natural forest/habitats) by wild mammals using camera traps deployed within grids (1 km<sup>2</sup>) for a period 10-15 days. Local peoples’ perception surveys were also carried out.

3. This study finds interesting patterns on how animals are using these areas without being in much of conflict (as in current study area). Major findings of the study includes a) there are species that are largely dependent on modified landscapes while others that are dependent mostly on natural habitats, b) there appears to be an adaptive strategy to avoid human interaction by adjusting activities in different time scale between natural forests and human dominated areas, c) factors that are responsible for occurrence of these species in various land use types, and hence getting an idea of what future holds for these animals and d) positive perception of local people that shows a light of hope on the conservation of animals in their lands. However, it cannot be done if locals do not get direct benefits by the presence of wild animals.

4. This study provides a baseline for a better understanding of such systems, which through further studies and effective management tools might provide option for conservation management and long-term viability of specific wildlife species that are capable of negotiating human presence.

# CHAPTER 01

## INTRODUCTION

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*“Ecologists traditionally have sought to study pristine ecosystems to try to get at the workings of nature without the confounding influences of human activity. But that approach is collapsing in the wake of scientist's realization that there are no places left on Earth that don't fall under humanity's shadow”.*

*-Richard Gallagher and Betsy Carpenter (1997)*

Human has always shaped land according to its will and as he is starting to explore new things, the change to its surrounding is dealing new consequences. Human modified landscapes, an art from pre-historic times of a hunter gatherer to agricultural systems and now to concrete walls all over the place makes us to realize, shaping Earth according to our will is not going to benefit any kind in the long run.

With the increase in human population, demand for land is also increasing; leading to habitat loss and fragmentation which are major threats to biodiversity (Noss et al. 1996, Western 2001 and Tigas et al. 2002). These fragmentations often result in habitat modifications of natural areas for human benefits, that has been classified as one of the most serious threats to biological diversity, apart from agricultural/horticulture crop fields, tea/coffee plantations and grazing land (Wilcove et al. 1998). Due to such alteration in land forms, wild animals are often forced to use human habitations either as corridors to disperse to other fragments, or to access resources, which inevitably results in negative interactions with humans (Yom-tov et al. 1995, Baker 2007 and Oro et al. 2013).

In order to reduce such anthropogenic influence on natural systems, Protected Areas (PAs) have been an important executive device throughout the world, to control and prevent the mindless felling of trees and land-use conversions (UNEP-WCMC). Today, protected areas cover 15.4% of terrestrial and inland water areas (Juffe-Bignoli et al. 2014). In India, we have 4.95% of country's geographical area under the PA category

(ENVIS bulletin 2017). However, the failure of conservation seems imminent, as 90% of tropical forests are outside PA network (WWF 2002) with continuous pressure of habitat modification and deforestation (DeFries et al. 2005). A lot of research has been done, suggesting the importance of understanding agricultural systems in the context of conserving biodiversity (Bennett et al. 2006, Harvey et al. 2008, Scherr and McNeely 2008 and Elsen et al. 2016). The latest report of UNEP-WCMC and IUCN (2016) on PAs across the world has incorporated productive systems (agriculture, aquacultures and forestry) to achieve its Aichi Biodiversity Target.

The Indian Himalayan region (IHR) has a network of 88 PAs, covering 9.7% of its geographical region. The mountain landscape is interspersed with community-conserved forests, which are in turn rich sources of fodder and fuelwood for the locals. Some communities modify patches of these forests for the purposes of agriculture/horticulture land. Small villages are mostly scattered and not clumped, unlike in cities or towns, making it possible for wild animals to use the diverse landforms, undetected. Hence, it makes Himalayan villages an exciting place to study usage by wild animals in the habitat mosaic that these areas provide. Despite above facts, human-modified areas have always been neglected from the conservation viewpoint.

Most of the studies in such landscapes have been focused on the negative interactions of wild animals with humans through the limited scope of just socio-economic surveys e.g. Treves and Karanth (2003), Agarwal et al. (2011), Charoo et al. (2011) and Bhatia et al. (2013). To understand the patterns clearly, we need scientific inputs for assessing the potential of the 'non-protected, human-dominated landscapes' in terms of conservation by developing methods for minimizing negative interactions between local people and wild animals.

Planning conservation in such landscapes is not possible without understanding the response of local people that reside there (Raman and Mudappa 2003). The settlers here, due to the remoteness faced in past years, are connected to forests and nature, as it is their sole lifeline. Most of these communities have conservation oriented views stemming from their cultural/religious beliefs (Negi 2010). However, these are the same people who face negative interactions with wildlife (Badola 2008). It is very clear from the above

points that understanding local communities' perceptions is very important for humans and wildlife to co-exist.

The Government of Uttarakhand has a developmental plan, touting world-class infrastructure, health and education, basic amenities in remotest areas and improved quality of life in hills. The aim seems to be to transform the state into a role model for a green economy and world leader in green energy ("Uttarakhand Vision 2022"). In spite of the mention of "green energy" and "green economy", development of the western Himalayan state might lead to drastic changes in land-use patterns which makes it even more important to provide information beforehand, on how altering these systems might affect wild animals.

The kind of pattern witnessed in the past several years, as to how areas fabled as hunting grounds were later converted to protected areas, to conserve the same (Smith 2013), cannot be continued any further. Now with an accentuated decline rate in natural forest patches and species diversity; the time has come to focus on areas outside PAs.

Due to global outcry on biodiversity harboured by agricultural areas, conservation authorities like United Nation Environment Programme (UNEP) and Ministry of Environment, Forest and Climate Change's (MoEF) scheme Integrated Development of Wildlife Habitats (IDWH), which are promoting conservation outside protected areas, focusing on agricultural fields, plantations and other human-modified areas. Hence, a basic understanding on the usage by wild animals of such areas is important.

## **1.1 Review of literature**

### **1.1.1 Agricultural landscape and biodiversity**

Many recent studies have focused on the role of agricultural landscapes in conservation of organisms of different taxa. The term 'eco-agriculture' has been coined for agricultural areas that can be managed to harbour wild animals as well as local farmers (Scherr and McNeely 2008) and have pointed out the requirement of research in this field.

Studies have revealed that agricultural landscapes serve as important components for the conservation of various species from different taxa (Pimentel et al. 2010 & Harvey et al.

2008). Habitat heterogeneity in such a landscape is considered to play the most crucial role (Benton et al. 2003, Bennett et al. 2006, Gardner et al. 2009, Osuri et al. 2010). Also, PAs in tropical countries are mostly surrounded by human settlements, offering a mosaic of heterogeneous land uses along with intense pressures on wildlife (Janzen 1983, DeFries et al. 2005 and DeFries et al. 2007).

Studies suggest that these areas might not be home to rare and highly threatened or charismatic species that call for PAs without human disturbance (Gardner et al. 2009), instead point out the occurrence of less sensitive or moderately resilient species which should not be ignored as they also provide important ecosystem services.

### **1.1.2 Human modified systems as a resource base for wildlife**

Species response towards human-modified landscapes have been suggested to be the consequence of life history, behavioural, and physiological attributes that promote their tolerance or preference towards human dominated landscapes (Gehrt 2014). Availability of primary resources such as food, mates, and refuges, also have been said to govern territoriality in animals, and hence affect their social behavior and density-dependent dynamics (Doncaster et al. 1991).

Studies ranging from urban, peri-urban and rural areas have found similar results for animals living in proximity to human-modified landscapes. Several studies on carnivores concluded that they seem to be mostly, or at times wholly dependent on anthropogenic food subsidies (Beckmann et al. 2003, Ditchkoff et al. 2006, Stempniewicz 2006, Abay et al. 2011 and Ghoshal et al. 2015). However, a preference in wild native diet of carnivores was observed mostly when natural resources were abundant over anthropogenic offers, as in different seasons (Blanchard 1987, Contesse et al. 2004, and Newsome et al. 2014). Also, it was found that the diet spectrum (ingredients) in urban areas was much higher than in wild areas (Adkins 1998, Fedriani et al. 2001, Beckmann et al. 2003 and Contesse et al. 2004). Other than diet, many studies have also shown how these animals flourish because of the abundance of resources, absence of large predators, and the occasional availability of shelter near or within these areas (Harris et al. 1981, Trehwella

et al. 1988, Rose and Polis 1998, and Sillero-Zubiri et al. 2004) also attributing to their ecological release (Gehrt and Prange 2006, Carbone et al. 2007 and Crooks et al. 2010). Some studies found reduction in home range sizes in such areas (Beckmann et al. 2003), while others found altered social behavior of group living in some generally-solitary canids such as foxes and jackals (Macdonald 1979, Adkins 1998, Baker et al. 2000, Sandra Gloor 2002 and Baker et al. 2004). According to a study on mountain lions, it was found that the social structure and land tenureship were not due to territoriality, but owing to food supply (Pierce 2000).

### **1.1.3 Synanthropic species**

Synanthropic species have been defined as “species that share and profit from the human ecotope but which are not dependent on a human-derived food supply. Synanthropic species can be further divided into those that live and breed in conurbations (resident species) and those where individuals only temporarily move in from surrounding habitats, principally to forage on human food waste, but do not breed (vagrant species) (Baker and Harris 2007).

Different studies have shown that such species are relatively more adaptable, and so can live in the confluence of natural and human dominant habitats (Macdonald 1979, Fedriani et al. 2001, Fuller et al. 2010 and Gehrt 2014). They show more tolerance to human mediated disturbance (Doncaster and Macdonald 1991, Tigas et al. 2002). Large distribution ranges and commonness of such species is an evidence of increased tolerance and adaptability (Sillero-Zubiri et al. 2004). Mckinney (2002) has classified different species into three categories of 1) ‘urban avoiders’, that avoid urban areas, are mostly specialists but are present in nearby forest patches (Crocchi and Clergeau 2008); 2) ‘urban adapters’, that have adapted themselves to human habitations and are seen in these areas but try to avoid humans directly, are mostly generalists and omnivorous (Gehrt 2014); and 3) ‘urban exploiters’, that exploit human resources even in the presence of humans (Kark et al. 2007).

#### **1.1.4 Cause and consequences of wild animals in human modified systems**

Although these areas provide food security to many animals, they also pose a threat to them. Human disturbances are not fatal, if indirect, but there are other human mediated factors that are a direct threat to the wild populations and in many cases are fatal. Cases of people inhumanely killing carnivores in retaliation are common on the news channels. This has been a cause of concern for conservationists of wild carnivores that are sometimes largely dependent on domestic prey species (Bagchi and Mishra 2006, Athreya et al. 2014). Linear-infrastructure is another such factor which has recently been viewed as a major threat to wildlife. Mortality rates caused due to collisions from vehicles/railway trains are increasingly being reported from different parts of the world and are also prevalent in agricultural systems (Caro et al. 2000).

Other than these, transmission of diseases through the wild-domestic animals' interface, is also a cause for concern (Bengis et al. 2002). Shepherding of livestock (and accompanying dogs) by humans and the higher number of animals taken inside forests also increase the probability of disease transmission (Fevre et al. 2006). Importantly, corridors or mosaic landscapes, where forests are close to human settlements, risk of disease transmission increases; which has been viewed as a reason of meta-population extinction (Hess 1994).

#### **1.1.5 Current state of knowledge**

Most of these studies have been done in countries of North America, England and Australia. In India there is a dearth of knowledge on the ecology of mammals found in confluence with human habitations. Most studies have focused on the negative interactions with very few examples on usage of wild animals for resources in rural areas (Kumara et al. 2004, Banerjee et al. 2013, and Ghoshal et al. 2015). Some studies, showing importance of matrix of forested and non-forested areas have been done in the Western Ghats but mostly on other vertebrates and invertebrates and negligible on mammals (Osuri et al. 2010).

Species that were common in the recent past have seen drastic decline in population such as the house sparrow (*Passer domesticus*) (Robinson et al. 2005), vultures *Gyps* spp. (Green et al. 2004), and golden jackal (*Canis aureus*) (Pillay et al. 2011) which points at

a need to understand the responses of common species to their changing environment. It is also interesting to study how these animals respond to these changing patterns in their diet and how this has led to many animals changing their ecology to drastic levels which can further be used in their conservation and population management.

It has been argued that ignoring agricultural landscapes is a failed strategy (Perfecto and Vandermeer 2008). As it is known, in the fragmented nature of most tropical ecosystems, agricultural landscapes provide land mosaics, allowing many species of plants and animals to sustain (Bennett et al. 2006), and hence it should be an essential component as a part of any conservation strategy (Perfecto and Vandermeer 2008). There are emerging evidences showing that large carnivores can also thrive in multi-use landscapes in tropical countries (Banerjee et al. 2013 and Muntifering et al. 2005). But due to dearth of knowledge of how mammalian species use human modified landscape, it becomes necessary to focus on these parameters with scientific studies.

Hence, on the basis of above discussed issues, there is an urgent need to focus on non-forested areas near natural forests and this study aims to provide such information on man-animal interface, to conserve these species at a landscape level for their long-term survival.

Following Gardner et al. (2009), “*areas which have not been significantly altered from native vegetation to urban cities but to land use such as agriculture, forestry, settlements and extractive use of forests, I define these areas as human-modified landscape*”. Since I’ll be looking at peoples’ perception in the conservation of these areas, as understanding this is important to bridge the gap for long term conservation (Raman and Mudappa 2003).

#### **1.1.6 The present study**

The present study focuses on the spatial and temporal patterns of wild mammals in different habitats to assess if there is any specific pattern in terms of space and time. Also, since these patterns are governed by drivers, either as attractants such as, food, shelter and cover or as repellants, habitat covariates and human mediated disturbances were also considered. I have also considered to look at peoples’ perception on problem as well as neutral or beneficial wild animals.

## **1.2 Objectives**

Keeping the above in view, a six month (December 2016 to May 2017) study on the wild mammalian species was carried out in human dominated landscape (towns/villages, agriculture/horticulture areas, secondary scrub/forests, degraded/barren areas adjoining natural forests) of Mandal sub-basin located along the southern boundary of Kedarnath Wildlife Sanctuary (WLS) in District Chamoli, Uttarakhand, India. The objectives of the study were:

1. To quantify the patterns and drivers of usage by wild mammals in human-modified landscape of Mandal Sub basin in Chamoli district, Uttarakhand.
2. To understand the perception by local people on wildlife use of their areas in the Mandal sub basin.

### **1.2.1 Research Questions**

1. Are there any specific patterns (spatial and temporal) for resource specific usage by wild mammals?
2. What mediates the usage of human dominated landscapes by wild mammals?
3. How do local people view and respond to these mammalian species?

## CHAPTER 02

### THE STUDY AREA

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#### 2.1 Location and description

Uttarakhand is one such state in the western Himalaya with 16,826 rural settlements of which 81% have less than 500 population size (ENVIS 2000) where agriculture is most dominant source of income. It has 13 districts of which Chamoli is one of them encompassing an area of around 7,900 km<sup>2</sup>, with a human population of 3,91,114 and literacy rate of 76.23% (“District census, 2011”). The Chamoli district encompasses the high mountain range that forms the upper catchment of Alaknanda, a major tributary of Ganges and its elevation range from 900m to 7,817m (Nanda Devi west peak) above sea level. The Chamoli district is well renowned for its high mountain peaks, glaciers, wilderness areas such as Nanda Devi National Park (NP), Valley of Flowers NP – both inscribed as a UNESCO World Heritage Site, Kedarnath WS, world famous pilgrim sites, and tourist areas. The present study was conducted in Mandal river sub-basin (30° 22’11.00”-29’11.25” N and 79°15’30.29”-15’30.30” E) near the southern boundary of Kedarnath WLS with Mandal/Balsruti or Balkhila and Amrit Ganga as perennial rivers and several small perennial and seasonal streams (*nullah*). The Mandal sub basin extends from a high ridge (3,400m) just below Chandrashila (3,680m) near Tungnath temple to its confluence with Alaknanda near Chamoli at 900m. This sub basin has mostly north and south facing slopes as Balsruti flows almost west to east and diverse slope and land use, land cover categories.

The highest temperature recorded during 1989-1991 near Mandal was 34°C and lowest 0°C with mean precipitation being more than 3,000 mm (Sathyakumar 1994). The study area is defined as Mandal river sub basin as extensive study area taking ridge line as boundary. The intensive study area however was restricted to sub-tropical to lower temperate altitude (900-2500 m elevation) to avoid species composition difference across.

The area consists of two towns viz., Gopeshwar, the district headquarters and Chamoli and 20 villages. These villages differ in number of households per village and have different proximity levels to forests.

Mandal sub basin has high habitat heterogeneity, with Kedarnath WLS touching its fringes to relatively less disturbed and contiguous forests, to highly disturbed forests, disturbed and fragmented forests, forests close to villages and secondary scrub which have occupied abandoned crop fields and other infrastructure ruins such as *neher* (water channels made for crop fields and village). Agricultural areas as well as orchards also served as habitat structure in our study. The major natural vegetation however includes Banj Oak (*Quercus leucotrichophora*), Rhododendron (*Rhododendron arboreum*), Chir pine (*Pinus roxburghii*) and a few sub-tropical species (Rawat et al. 1999). It also had small patches of *Alnus nepalensis* and mixed forests of *Neolitsea pallens* and rhododendron tree above 2000m.

The study area has wide diversity of mammalian fauna including common leopard (*Panthera pardus*), Asiatic black bear (*Ursus thibetanus*), red fox (*Vulpes vulpes*), Himalayan palm civet (*Paguma larvata*), leopard cat (*Prionailurus bengalensis*), jungle cat (*Felis chaus*), Himalayan yellow-throated marten (*Martes flavigula*) jackal (*Canis aureus*), and ungulate species such as wild pig (*Sus scrofa*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), Himalayan serow (*Capricornis thar*), goral (*Nemorhaedus goral bedfordi*), and primates including Himalayan langur (*Semnopithecus schistaceus*) and rhesus macaque (*Macaca mulatta*). Other mammals include the Indian crested porcupine (*Hystrix indica*), red giant flying squirrel (*Petaurista petaurista*), other rodents and chiropterans (Sathyakumar 1994).

Local people in the study area are mostly dependent on forest resources and agriculture as their main sources of livelihood with some pastoral communities. However, those settled in towns such as Gopeshwar and Chamoli had people mostly settled from elsewhere who did not own agricultural lands. Gopeshwar has lost majority of its agricultural fields to concrete buildings with small patches left on the edges and one in the center. Residents of Gopeshwar also have protected a patch of planted oak forests, wherein lopping or cutting is restricted (Rawat et al. 1999). Pressure of lopping and cutting varies with

different *van panchayat*. However, sense of protecting forests and its importance is valued by majority of the villagers as observed during the study.

Since there is no hard boundary or complete edge of different habitat types, trails coming from forests lead to village and agricultural land, it makes it easy for wild animals to pass through different habitat types. Hence an area that is a mosaic of different land use types was selected for the study.

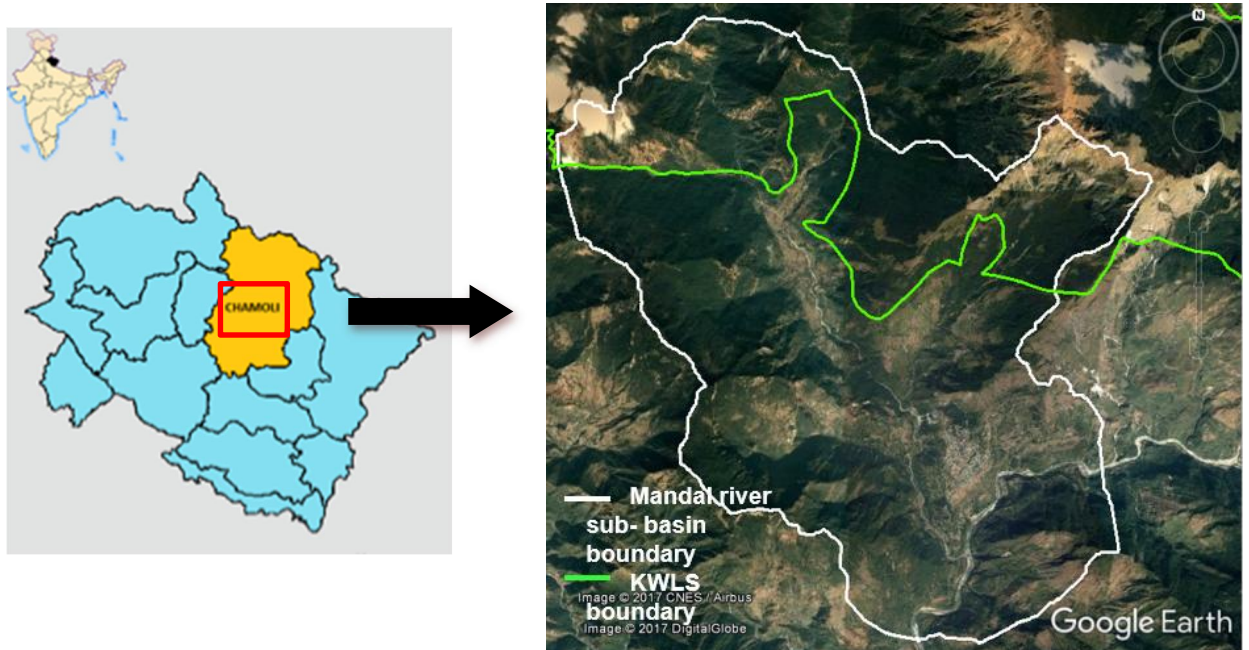


Figure 2.1: A map of the study area showing Gopeshwar-Mandal region and boundary of Kedarnath Wildlife Sanctuary passing through the study area, Chamoli district, Uttarakhand.

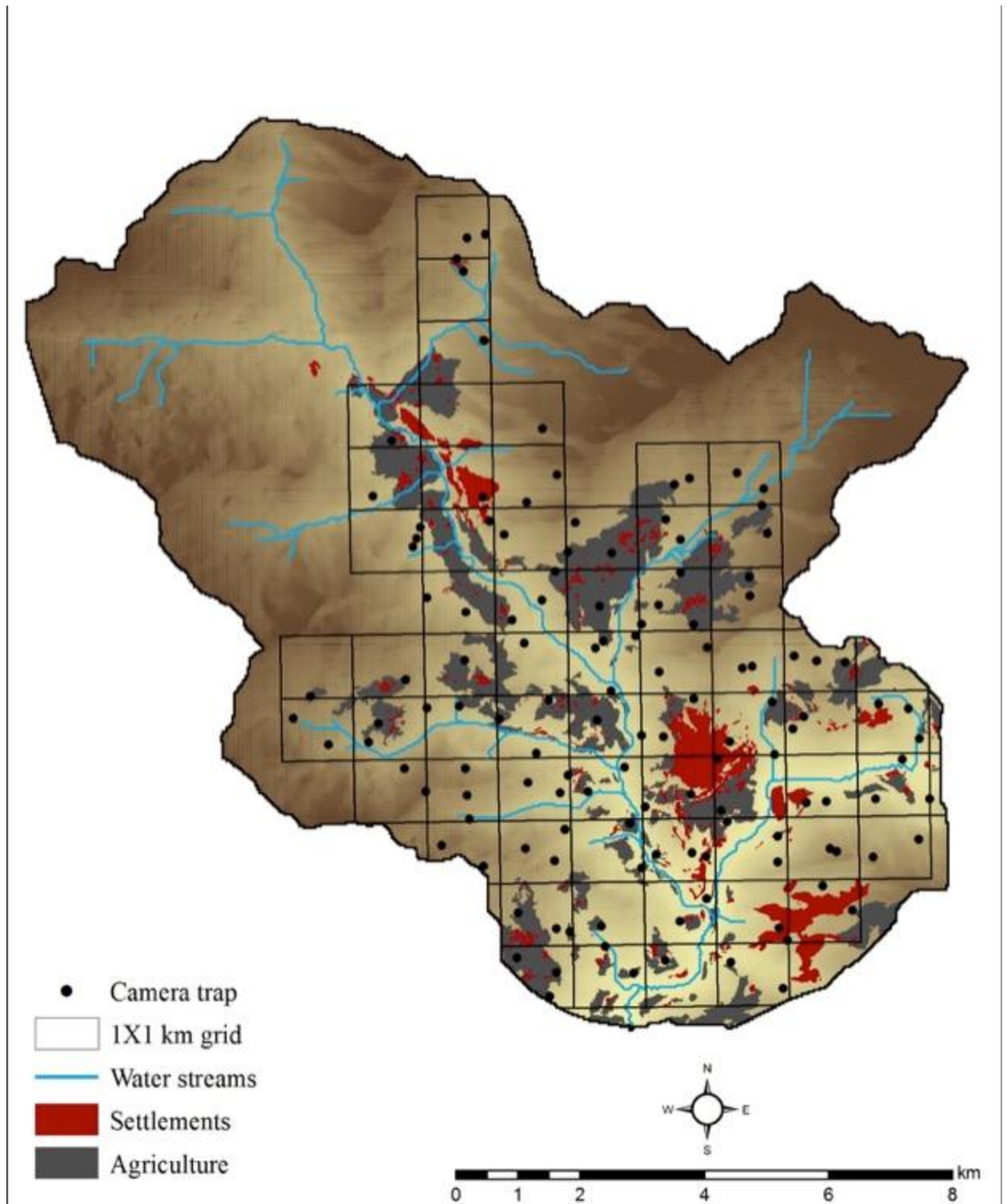


Figure 2.2: Map showing study area with sampled camera trap locations on a Digital Elevation Model (DEM) base in Mandal river sub-basin, Chamoli District, Uttarakhand, India



Figure 2.3: Gopeshwar town within the study area

## **2.2. Study design**

### **2.2.1 Spatial and temporal patterns and drivers**

Camera trapping was done across the study area to estimate the spatial and temporal patterns of wild mammals within it. It is a non-invasive method for estimating range of analytical methods used for different objectives. This instrument by default also keeps record of date and time of photo captured. I used Cuddeback model C-1 in my study with white flash cameras.

Grids of 1x1 km were laid and according to habitat heterogeneity within grids, minimum of 1 to maximum of 3 camera traps were placed. Such method was incorporated to cover different species with different home range sizes, body sizes and behavioral patterns in different land-use types. Area was intensively searched for signs, including droppings/tracks/scent marks and for resources like garbage dumps and agricultural lands

with or without crops sown. In areas like crop fields, trails coming from forests were followed. However, areas with large agricultural lands, sign surveys &/or presence of water &/or trails connecting two villages or leading to forests were chosen to maximize capture rates. Locations told by villagers were not reliable as they mostly had biased view on problem animals getting photographed in/near their village. However, from clues given by them, area was prioritized and after proper survey a trap location was chosen. Camera trap locations were selected after 1 and a half month of reconnaissance. Camera trapping was started in January 2017 from low elevation zones and conducted till April 2017 in higher elevation zones to maintain effect of temperature on occurrence of species. Sampling was done once per grid without repetitions by shifting cameras to other grids after each session.



Figure 2.4: One of the grids representing camera trap placement (camera 1 (in moist forest), 2 (mosaic) and 3 (degraded forest)).

Vegetation sampling was done for each camera trap location taking 15 m radial plots, covering trees, shrubs and herbs present. These plots were more than 150m apart. Elevation, aspect, slope, terrain and ground cover were also recorded for each camera trap.

Human disturbances, such as logging (for fuel/fodder), grass cutting/fodder/litter collection and pellet/dung/scat plots were recorded for wild as well as domestic animals within the plot.

### **2.2.2 Local People Perception surveys**

To understand perception of local villagers on wild species, my questions were majorly focused on assessing perception of local people towards conflict as well as non-conflict animals. Of the total 22 villages present in the study area, 16 villages were surveyed based on distance from forest, type of forest in proximity, size, elevation and their distance to each other. Villages in close proximity to each other were avoided to negate the effects of spatial autocorrelation.

## CHAPTER 03

### METHODS

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#### 3.1 Field Methods

##### 3.1.1 Assessment of spatial and temporal patterns

A total of 140 camera trap points were sampled in 68 grids covering areas from highest populated towns to smallest villages (within study area) as well as agricultural fields, protected and unprotected forests along with orchards, garbage dump sites, planted forests, secondary shrub lands. Mean sampling session in the study area was  $14.82 \pm 0.67$  trap nights. However due to malfunctioning of camera traps and 3 camera traps being stolen, 131 functional camera traps covering 64 grids were analyzed.

GPS location of camera trap was taken using Garmin e-trex 30 model GPS. Most of the areas were covered by walking which was  $\sim 1300$  km while motorable vehicles were used to reach far off villages. Traps were placed strategically (**Appendix 5**), and set to capture photographs at 5 seconds interval to maximize detection. In certain points though, time was set to 10 to 15 seconds interval wherever probability of false captures was high. Based on habitat types (**Table 3.1 (b)**), camera traps were placed proportionately in each habitat in the study area.

The Mandal sub basin was divided into five elevation zones of 300m each (**Table 3.1 (a)**).

a) Elevation zones

Elevation ranges	# of camera traps placed
900-1200	23
1200-1500	35
1500-1800	46
1800-2100	25
2100-2400	8

b) Habitat types

Habitat type	Code	# of camera traps placed	% of sampling efforts
Moist forest	Mf	45	33.33
Dry forest	Df	26	19.26
Secondary scrub land	Ss	9	6.67
Mosaic of crop field and forest	Mo	20	14.81
Crop fields	Cf	17	12.59
Near human settlement	ns	18	13.33

Table 3.1: Sampling effort in different elevation zones (a) and habitat types (b) within study area. Since the area is dominated by moist forest, effort was high due to proportion of area it covers.

During vegetation sampling (**Appendix 5**), average canopy cover in three plots were taken to represent canopy cover of camera trap point location as represented in **Table 3.2**.

Percent canopy cover	# of camera trap points
>50%	14
>40 but <50%	10
>30 but <40%	10
>20 but <30%	11
>10 but <20%	18
>0 but <10%	41
0%	22

Table 3.2: Sampling effort in different categories of percent canopy cover.

Data analysis was done based on actual percent cover of both tree and shrub. Sampling effort was high in low canopy cover area as most of the areas were disturbed due to cutting/lopping or camera trap being in agricultural field or near settlement.

### **3.1.2 Habitat sampling**

I categorized habitat in the study area into six types as below:

Crop fields: *Large agricultural lands, with or without crops, where camera trap was placed between the fields where animals coming in search of food would come mostly. These areas also may or may not have cowsheds in between or on the edges.*

Mosaic: *Trails coming from forests and passing from edge of the crop fields and not in between, which animals might be using to pass to other habitat types and not specifically for crops or rodents, for example, in crop fields. These trails might pass on to other agricultural land, forest patch or human settlement. Species such as carnivores are expected to be using these areas more than large agricultural lands.*

Near settlement: *Trails close to human settlements, house mostly or between settlements. For present study a mean distance of 10 m was kept from nearest house.*

These areas apart from having other anthropogenic food subsidies, also had small crop fields for vegetables which people sow for their personal use and are not sown in large agricultural areas. Although there is no proper waste management, villagers segregated biodegradable (palatable) waste and either gave it to their cattle or used them as manure for crop fields. Hence anthropogenic food resource in terms of garbage was not clumped but an opportunistic factor of eatables thrown by children in nearby places.

Secondary scrubland: *Areas that earlier were crop fields or other human-modified areas but now have been abandoned since years and are taken over by successional scrub species such as Berberis sp., Rubus spp., Lantana camara and other scrub that make it difficult to be passed by humans. Knowledge on such habitat was acquired by field assistants who also were locals from nearby settlements.*

Dry forest: Natural forests of chir pine and/or *Alnus nepalensis* with majority of ground substrate of sandy/rocky/gravelly. These also include degraded open forests.

Moist forest: Natural forests of Oak species, *Rhododendron* species, *Neolitsea pallens* and other sub-tropical trees with majority of ground substrate being clayey to silt. Rocky and gravelly were also considered in moist forest if surrounding habitat had any of above mentioned forest types.

A pictorial representation of categorized habitat types has been given in **Appendix 5**.

Radial plots of 15 m radius were sampled at each camera trap location for taking co-variates of the trap as well as for assessing human disturbance. Number of trees of different species within plots, were counted. Shrub cover and tree and shrub phenology were recorded. Canopy cover was estimated using densiometer at 3 locations where ground cover for herbs, weeds and grasses was also done. Number of trees cut and lopped was counted. Grass cutting was assessed by asking locals, as cutting grass was either seasonal or pattern of tenure-ship at different plots making signs of grass cutting unreliable.

### **3.1.3 Local people perception surveys**

Data for human population of 22 villages within study area were taken from *Nagar Nigam Parishad* of 2011 census data. Population was later reconfirmed from village headman of village wherever possible. I sampled 5% of the population of 16 selected villages while from town only targeted group of people i.e. farmers, were interviewed. A total of 105 villagers were interviewed.

Questions asked during interviews are listed in **Table 3.3**. Approximately 30 min to 1 hour was spent in each questionnaire (**Appendix 5**). To reduce bias of response during questionnaire, light conversations were made with locals of few villagers wherever stay was possible, however, no such bias was found.

Perception on conflict as well as non-conflict animals (asked as animals that do not cause harm but use agricultural land, giving example of yellow-throated marten/ jungle cat/ leopard cat) was asked. People who perceived them as threat, answered accordingly.

Questions	Answers
Perception on “non-harmful” animals	Positive/ neutral/ negative
If they believed in co-existence with non-harmful animals	Positive/ conditional/ negative
If they get any benefits due to presence of wild animals	Positive/ both/ negative
What would be their feelings if wild animals get extinct from their surroundings	Happy/ sad/ depends on species (conflict/non-conflict)
If they believed in conservation of wildlife	Positive/ neutral/ negative
Kind of measures government should take against conflict animals	Positive/ neutral/ lethal

Table 3.3: Questions asked to understand the perception of local people on wildlife

Apart from these, I also asked people of what kind of development did they want and by their answers, level of destruction to forests or agricultural land were ranked as represented in **Table 3.4**.

Question	Answer	Rank
<b>Kind of development they want for their village</b>	No threat to forests in fact employment along with nature or for conservation	Low
	No threat to forests but agricultural lands can be converted to different land-use type	Medium
	Conversion of forested area as well as crop fields for the development and employment to villagers	High/Very high

Table 3.4: Categories of answers on extent of natural land conversion to different land-use types for village development and employment

## **3.2 Analytical methods**

### **3.2.1 Spatial pattern**

Species richness was plotted for large and medium wild mammals in six habitat types to have an overview of diversity in each habitat type.

#### **Sampling adequacy**

Species accumulation curves were plotted to assess sampling adequacy in each habitat types and also for the study area. These curves are used to record cumulative number of species in a particular environment as a function of cumulative effort expended searching for them. Chao 2 and Jackknife estimators were used which are considered to be the most effective estimators (Chazdon et al. 1998). These estimators extrapolate data to find true number of species that may have been present in the environment.

#### **Intensity of habitat usage**

Matrix of camera traps with habitat types was constructed for all species in MS Excel 2016 and graphs were plotted with the mean and standard errors of photo-capture rate per 100 trap nights, for individual wild species in different habitat types. These graphs gave an understanding on intensity of usage in the habitat types.

The matrix was also used to run Kruskal Wallis test in software PAST which is a rank based non-parametric test, used to assess statistically significant differences between two or more group of independent variables. This test was used to assess significant difference in relative abundance (mean photo-capture rate) of different species in different habitat types.

### **3.2.2 Temporal pattern**

Time of data retrieved from camera traps were used to estimate temporal activity patterns. For this analysis, time of photo-captures was used and was divided into two broad habitats, natural or forest habitats and non-natural or human-modified areas which included secondary scrub land, mosaic habitats, crop fields and areas near human

settlement. All the human-modified areas are also close to human settlements and it is expected that animals would have difference in activity pattern in both the areas.

The data was analyzed using R studio with package camtrapR to get summarized information of date and time and capture matrix for all species. Circular statistics looking to temporal pattern of animal captures, reflecting time-specific behavioral response of the species, were carried out and plotted using ORIANA software. Watson  $U^2$  test, was used for comparing temporal activity pattern of wild mammals in natural and human-modified areas. It is a non-parametric test used to find significance in difference between two or more samples.

### **3.2.3 Drivers**

Single species occupancy model is used as a tool for estimating true populations (Mackenzie et al. 2002). However, this model can also be used to determine habitat variables that describe sites occupied by species (or not) (MacKenzie 2006). It develops habitat models or predicts occupancy of a species based on habitat variables to which a species responds. This model was used to estimate influence of various habitat factors on the occupancy of a species.

Matrix of presence (1) and absence (0) was created for individual species with Z transformed values of co-variates. The co-variates selected for analysis of each camera trap are -

Co-variates extracted through GIS:

- Elevation
- Slope
- Aspect
- Distance to settlement
- Distance to agriculture
- Area of settlement
- Area of agriculture

#### Co-variates extracted during field sampling

- Shrub cover
- Canopy cover
- Number of trees
- Grass and herb cover

#### Co-variates extracted through camera trap data

- Human
- Domestic animals (dog + sheep + cattle)
- Wild prey animals (barking deer + sambar + wild pig + goral + porcupine)

Proportion of sites occupied by each species was plotted as depicted in the best combination of the site covariates in the best model/ models in terms of least AIC (Akaike Information Criterion) value. Occupancy of each species was done at the grid level. The slope and associated standard errors were used to understand the impact of the site covariates as drivers of occupancy of any particular site by any particular species.

### 3.2.4 Peoples' perception

A total of 16 villages were selected for sampling and were further grouped into five areas. Factors for categorizing villages into groups are shown in **Table 3.5**. Data was analyzed using Excel where stacked bar graphs were made showing percent of people having positive/neutral and negative perception about wildlife.

Area	Name of villages	No. of household sampled	Parameters
Area 1 Highly Degraded Areas (HDA)	Rangtoli, Golim, Chamoli	15	Degraded dry forests, less agricultural area and large area under human settlement (dependence on agriculture~ negligible)
Area 2 Towns with small forest patch (TSF)	Gopeshwar, Kothiyal sain, Rauli, Pilang	34	Towns with remnant forest patches, large area under human settlements with high intensification, and low area under agriculture (dependence on agriculture~ negligible)
Area 3 Villages with moderate agriculture (VMA)	Bachher, Bamyala, Tangsa, Siron	23	Villages surrounded by unprotected contiguous mixed and dry forests, large area under settlement with medium intensification, medium area under agriculture (dependence on agriculture~ medium)
Area 4 Villages on higher slopes close to forest (VHS)	Dewaldhar, Gangol gaon, Saggar	21	Villages adjacent to sanctuary, touching its fringes near ridge, contiguous moist forest, high area under agriculture with large human settlements (dependence on agriculture~ high)
Area 5 Villages in the valleys close to forest (VVF)	Siroli, Bairagana, Koteswar, Ansuya	12	Small villages, adjacent to sanctuary with contiguous forests, moderate area under agriculture with moderate intensity of human settlements (dependence on agriculture~ high)

Table 3.5: Criteria on the basis of which villages were grouped into five categories

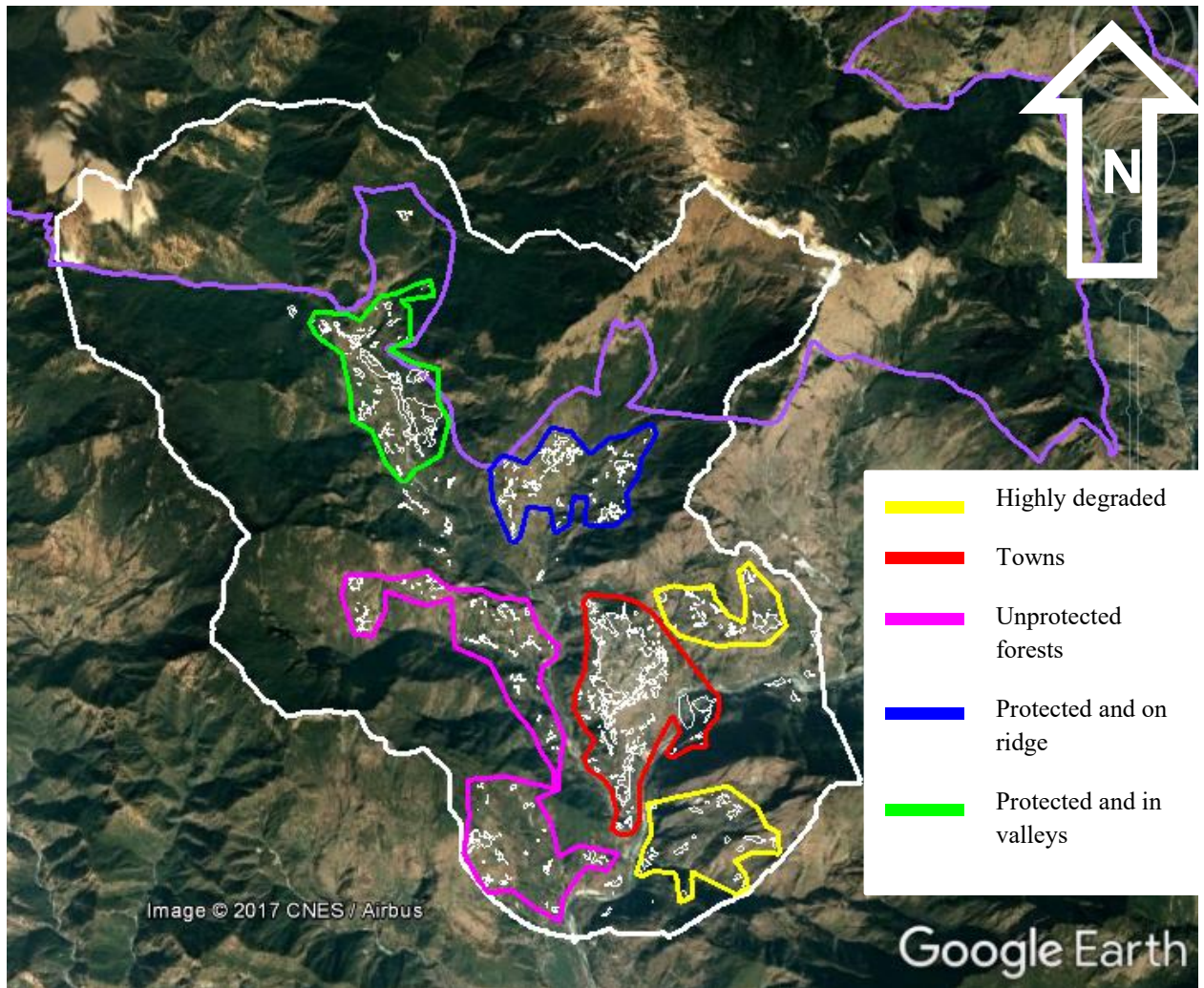


Figure 3.1: Map of 5 categories of villages in the study area (white boundary) and Kedarnath wildlife sanctuary (purple boundary)

## CHAPTER 04

### RESULTS

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#### 4.1 Spatial pattern

In total, 16 species of wild mammals used the study area, (**Appendix 1**) of which Jackal and Asiatic Black bear had very low photo captures and were not used further in other analyses. Number of different species detected in each habitat was plotted against different habitat types to get species richness in each (**Figure 4.1**).

Species richness was found to be highest in crop fields. Graph shows maximum species richness in crop fields (n=15) with least species richness near settlement (n=9) (**Figure 4.1**).

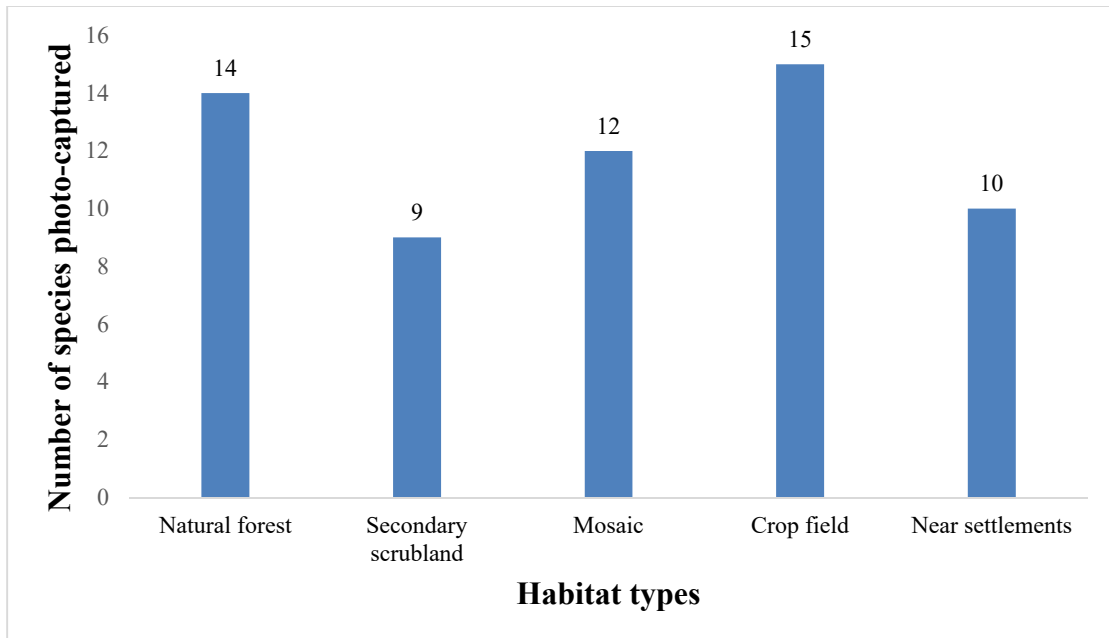


Figure 4.1: Mammal species richness in Mandal Sub basin, Chamoli district, Uttarakhand, December 2016-April 2017

#### Sampling adequacy

Adequacy of sampling was tested for all habitat types by plotting species accumulation curves. **Figure 4.2** represents sampling adequacy in five habitat types where asymptote is

reached for all habitats except for crop fields where Chao 2 estimator gave a value of  $17.35 \pm 3.00$  while Jackknife gave estimate of  $19.71 \pm 2.66$  species (**Table 4.1**). While **Figure 4.3** represents sampling adequacy for entire study area which depicts sampling was adequate. The red line shows the mean whereas blue lines are the standard deviations from the mean.

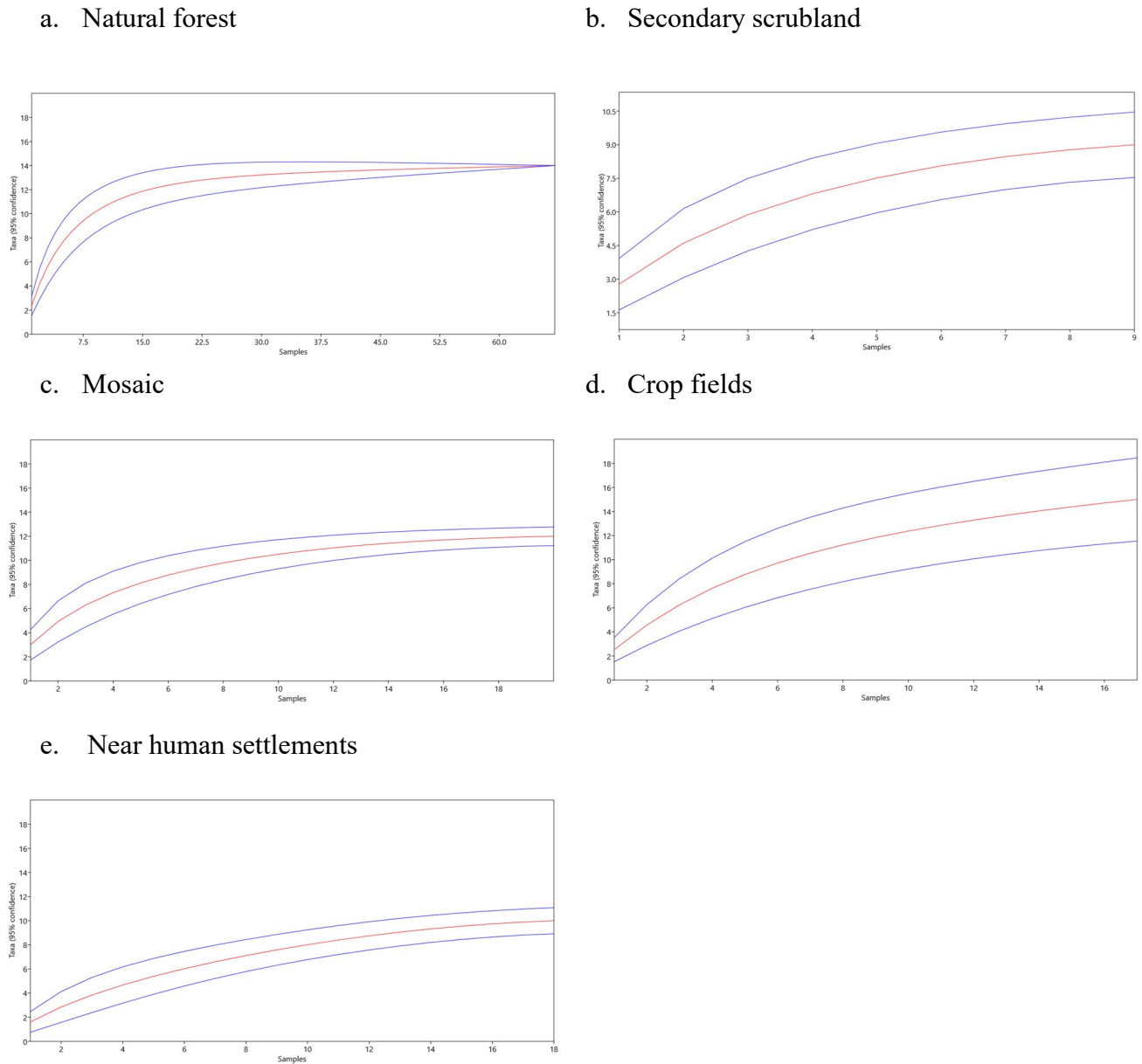


Figure 4.2: Species accumulation curves for five habitat types (a, b, c, d, and e) in Mandal sub basin, Chamoli district, Uttarakhand

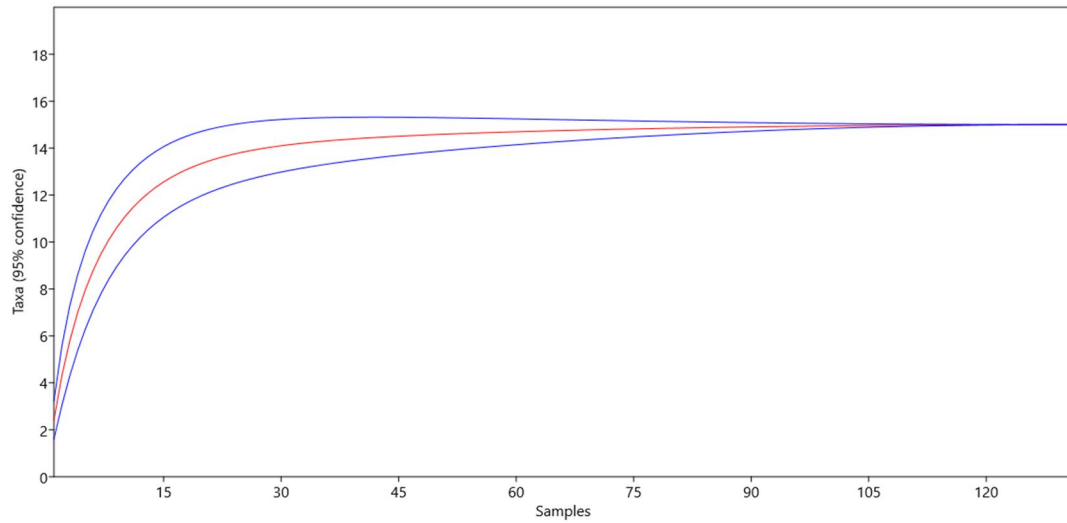


Figure 4.3: Species accumulation curve for entire Mandal sub basin, Chamoli district, Uttarakhand

Habitat type	Species observed	Chao 2 estimator value $\pm$ S.E.	Jackknife value $\pm$ S.E.
<b>Study area</b>	15	15.00 $\pm$ 0.00	15.00 $\pm$ 0.00
<b>Natural forest</b>	14	14.00 $\pm$ 0.47	14.99 $\pm$ 0.99
<b>Secondary scrub land</b>	9	9.22 $\pm$ 0.67	10.78 $\pm$ 1.18
<b>Mosaic</b>	12	12.00 $\pm$ 0.12	12.95 $\pm$ 0.95
<b>Crop field</b>	15	17.35 $\pm$ 3.00	19.71 $\pm$ 2.66
<b>Near human settlements</b>	10	10.13 $\pm$ 0.47	11.89 $\pm$ 1.30

Table 4.1: Species observed and Chao 2 estimator and Jackknife values for study area and five habitat types in Mandal sub basin, Chamoli district, Uttarakhand

### Intensity of habitat usage

Different species had different response to habitat types in the study area. The value of mean with standard errors have been presented in **Appendix 2**. Both primates had similar pattern however Macaque had high usage in secondary scrub land and areas near to human settlements while Himalayan langur was captured more in areas near human settlements followed by crop fields and moist forests (**Figure 4.4**).

a. Primates

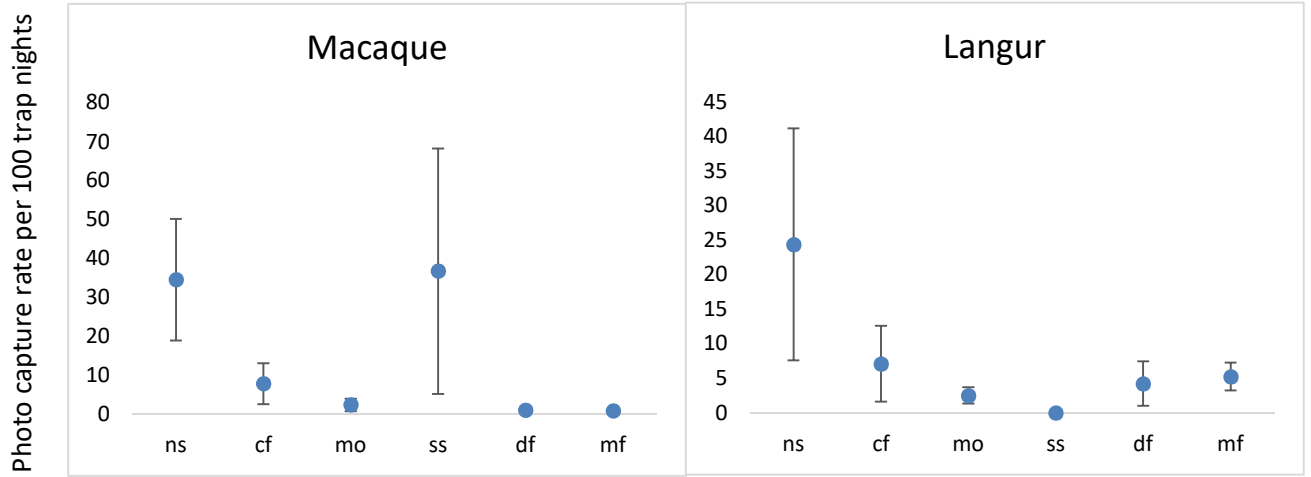


Figure 4.4: Mean photo-captures with standard errors of primates in different habitat types of Mandal sub basin, Chamoli district, Uttarakhand during December 2016 to April 2017

b. Large carnivore

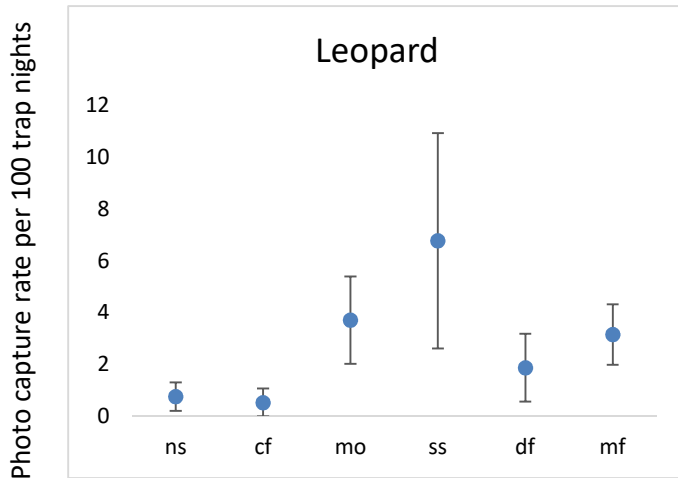


Figure 4.5: Mean photo-captures with standard errors of common leopard in different habitat types of Mandal sub basin, Chamoli district, Uttarakhand during December 2016 to April 2017

c. Small carnivores

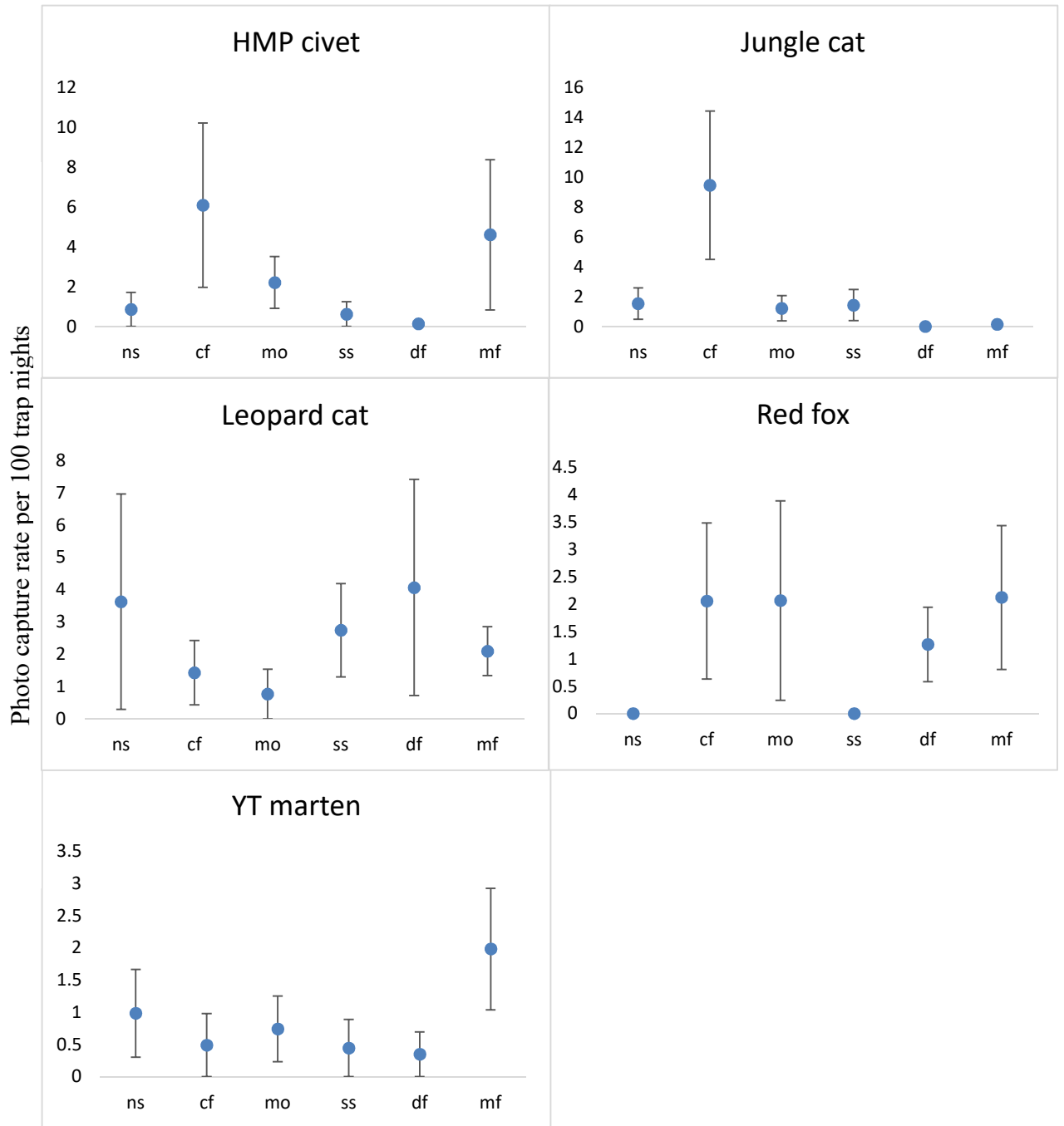


Figure 4.6: Mean photo-captures with standard errors of small carnivores in different habitat types of Mandal sub basin, Chamoli district, Uttarakhand during December 2016 to April 2017

d. Ungulates

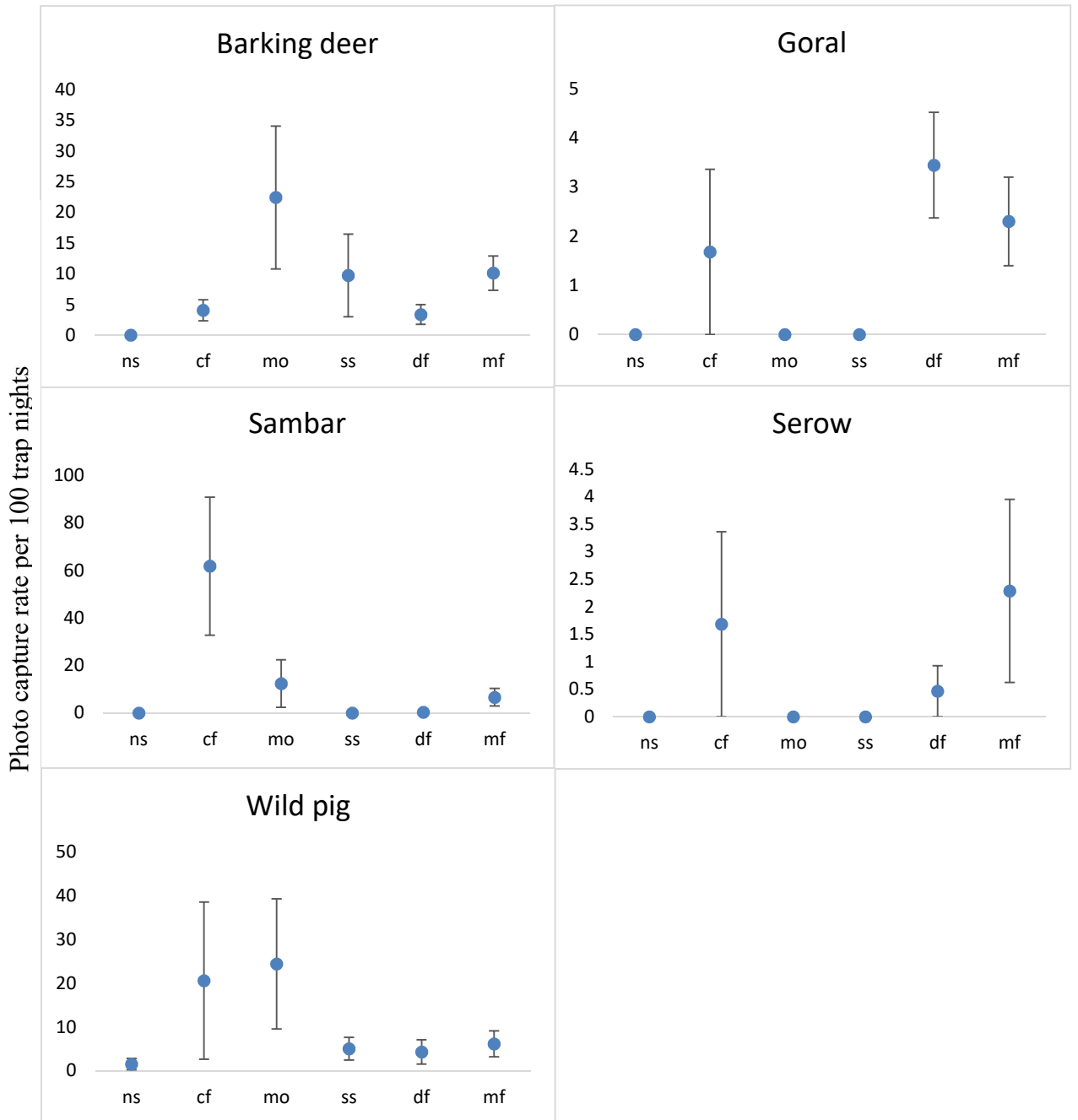


Figure 4.7: Mean photo-captures with standard errors of ungulates in different habitat types of Mandal sub basin, Chamoli district, Uttarakhand during December 2016 to April 2017

e. Rodent

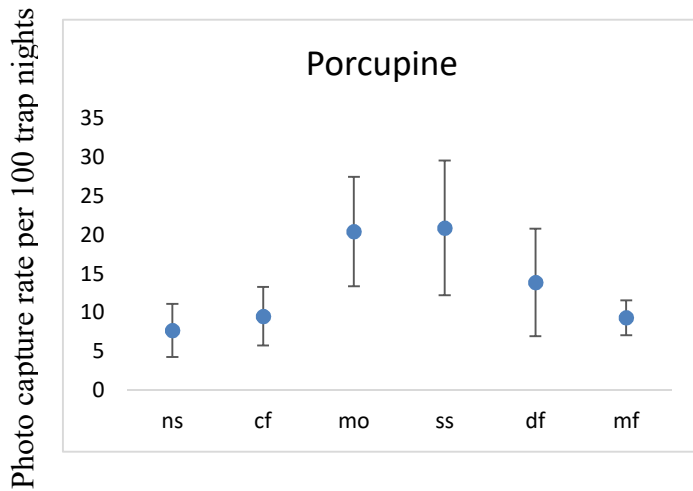


Figure 4.8: Mean capture rate per 100 trap nights with standard errors of Indian crested porcupine in response to different habitat types of Mandal sub basin, Chamoli district, Uttarakhand during December 2016 to April 2017

Large carnivore species, leopard used almost all the habitats with high standard errors showing insignificant usage in crop fields and near settlements.

Small mammals such as jungle cat and Himalayan masked palm civet showed high affinity to crop fields. Jungle cat was photo-captured only once in natural forests and had high captures in agricultural areas. However, other species such as leopard cat, yellow-throated marten and porcupine seem to be using almost all the areas. Red fox showed a trend of not using areas near settlements or secondary scrubland.

Ungulate species such as barking deer, goral, serow and sambar were never captured near settlements with wild pig showing insignificant value for such areas. While goral and serow had minimal use of disturbed areas like mosaic, secondary scrub land and crop fields, sambar and wild pig showed high usage in crop fields. **Table 4.2** lists species with significant difference in mean photo-capture rates in habitat types as depicted by independent-samples Kruskal-Wallis test.

Independent samples Kruskal-Wallis test	
Species	Significance
Barking deer	0.049
Goral	0.004
Jungle cat	0.016
Macaque	0.001
Sambar	0.043
Wild pig	0.009

Table 4.2: Species with significant difference in mean photo-capture rates in all habitat types in Mandal sub basin, Chamoli district, Uttarakhand

#### 4.2 Temporal activity

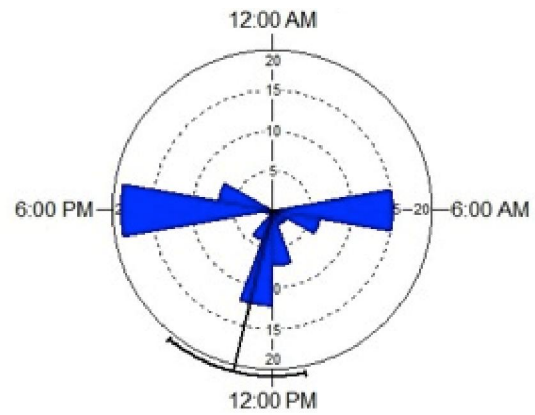
Rose diagrams of temporal activity are represented in **Figure 4.9** to **Figure 4.13**. Red line in the graphs indicate wider deviation from the expected directionality. **Table 4.3** shows the significance in difference in temporal activity for different species. Species like Himalayan masked palm civet, red fox, yellow-throated marten and barking deer showed no significant difference in temporal activity pattern in the two habitats while other species like Himalayan langur, rhesus macaque, wild pig, porcupine, leopard, leopard cat and sambar had significant difference for the same (**Table 4.3**). Jungle cat, serow and goral could not be calculated because of low captures in either of the habitat (**Table 4.3**).

**a. PRIMATES**

**Himalayan langur**

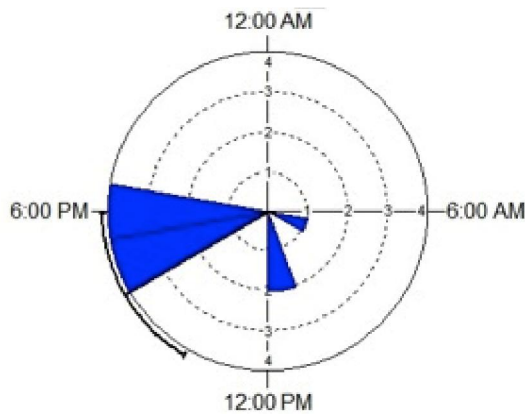


**Forest**

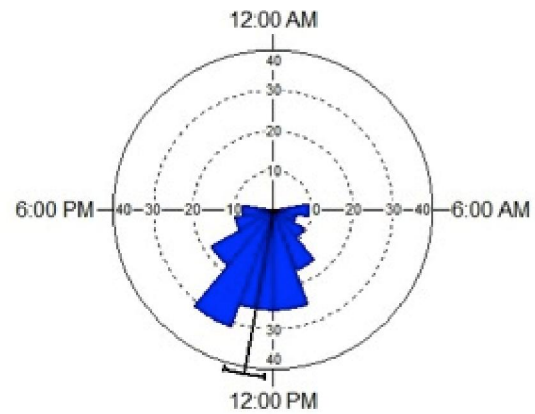


**Non-forest**

**Rhesus macaque**



**Forest**



**Non-forest**

Figure 4.9: Temporal activity pattern of primates in natural habitats or forest\* and human-modified or non-forest\* habitats

\* Forest include natural moist forests, dry forests and degraded open forest while non-forest includes human modified areas like secondary scrubland, mosaic, crop fields and settlement areas.

**b. Large carnivore**  
**Leopard**

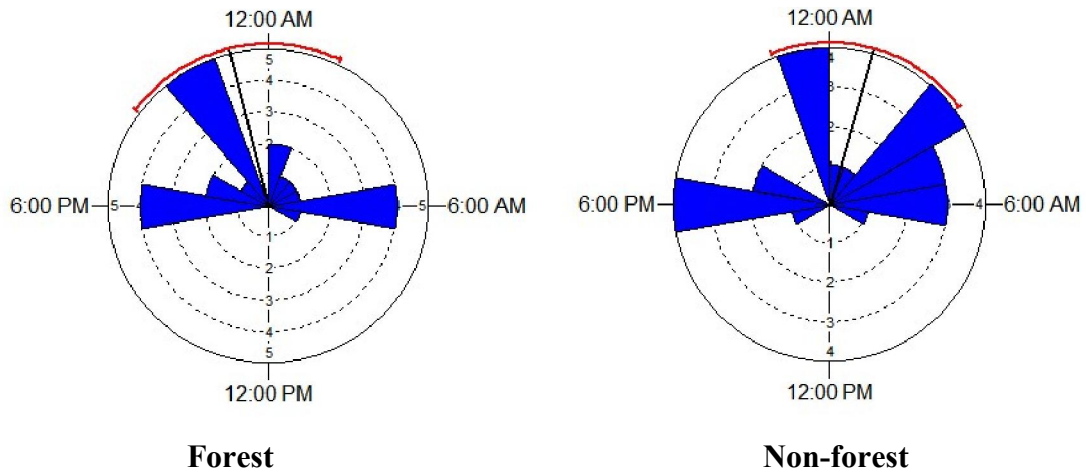
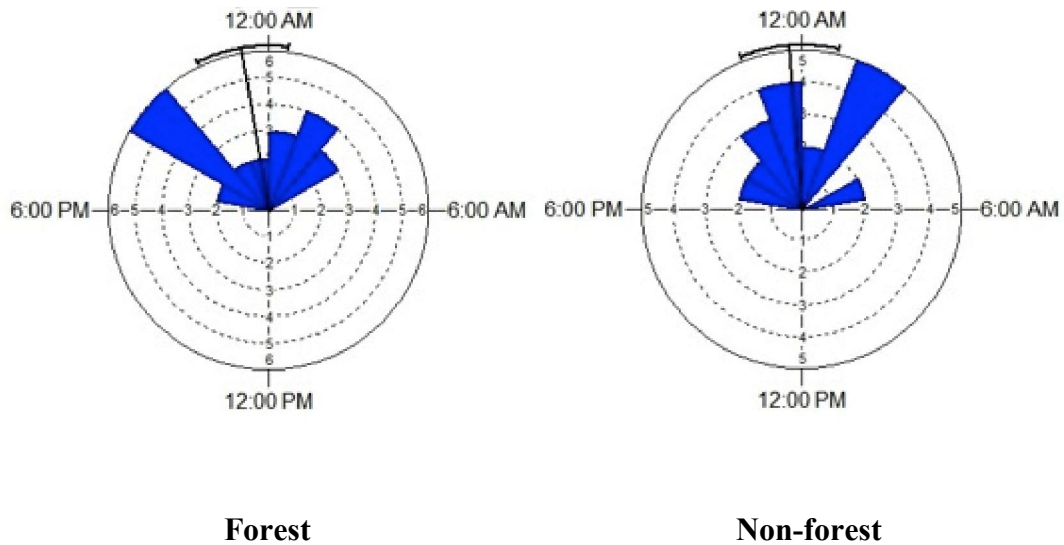


Figure 4.10: Temporal activity pattern of large carnivore in natural habitats or forest and human-modified or non-forest habitats

**c. SMALL CARNIVORES**  
**Himalayan masked palm civet**



### Jungle cat

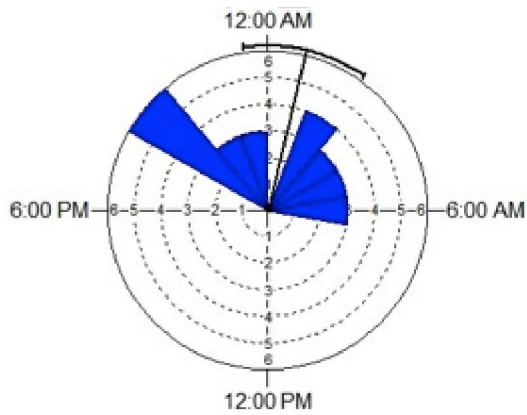


Forest



Non-forest

### Leopard cat

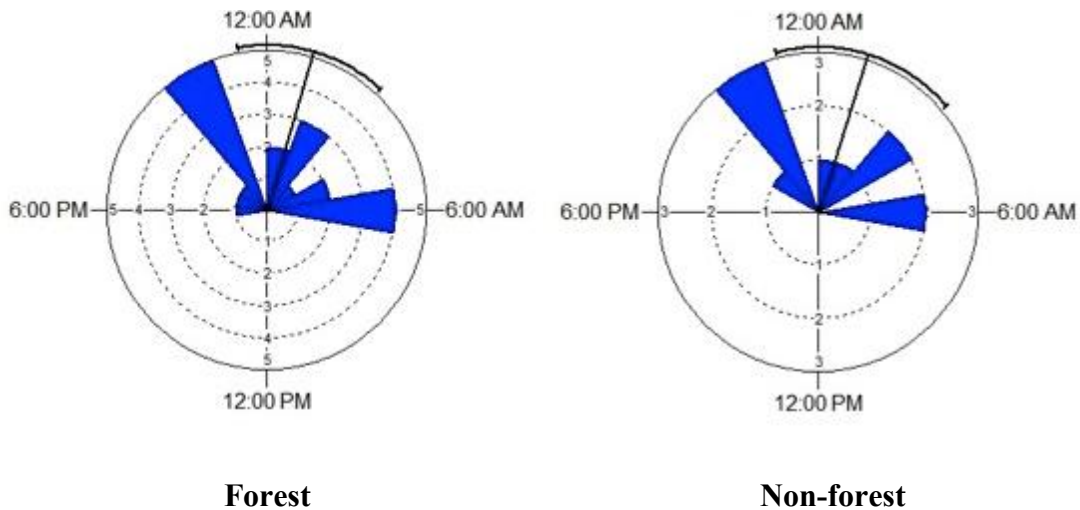


Forest



Non-forest

**Red fox**



**Yellow throated marten**

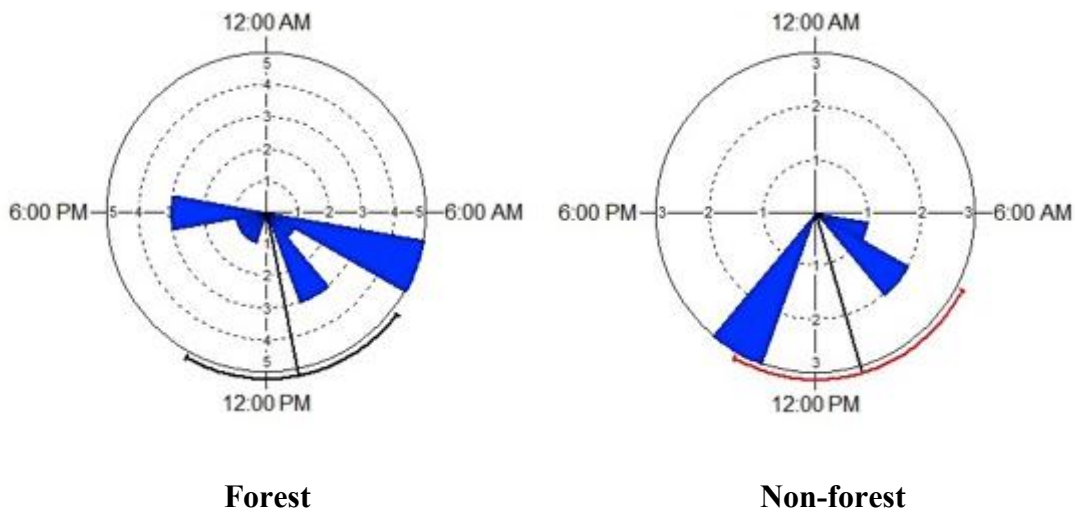
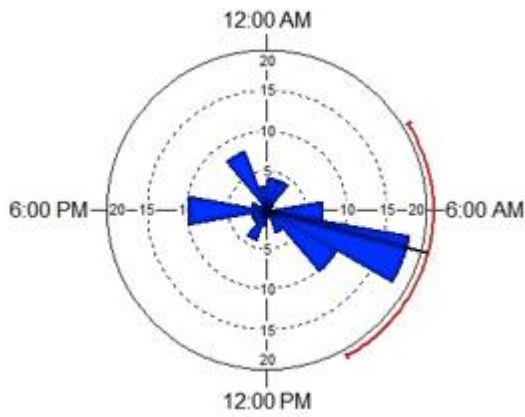


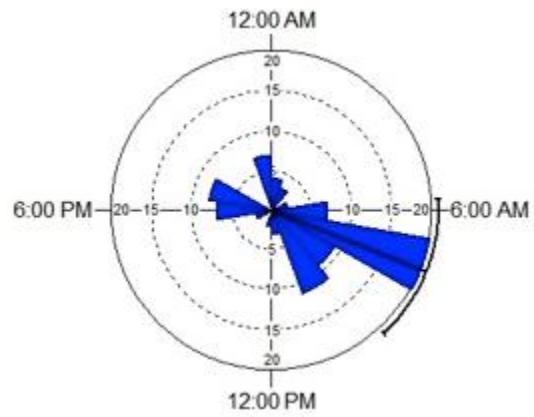
Figure 4.11: Temporal activity pattern of small carnivores in natural habitats or forest and human-modified or non-forest habitats

**d. UNGULATES**

**Barking deer**



**Forest**



**Non-forest**

**Goral**



**Forest**



**Non-forest**

### Sambar



**Forest**



**Non-forest**

### Serow



**Forest**



**Non-forest**

**Wild pig**

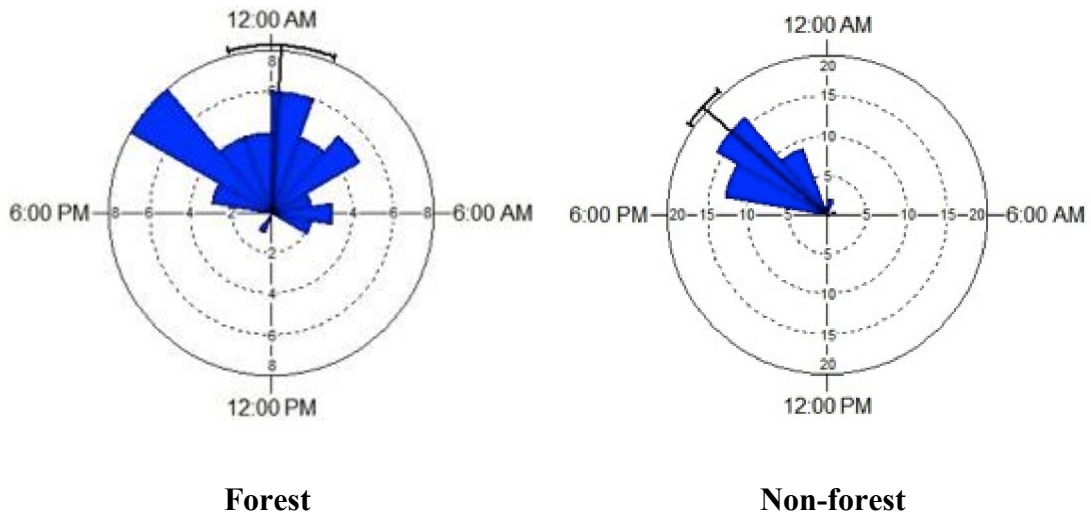


Figure 4.12: Temporal activity pattern of ungulates in natural habitats or forest and human-modified or non-forest habitats

**e. RODENT**

**Porcupine**

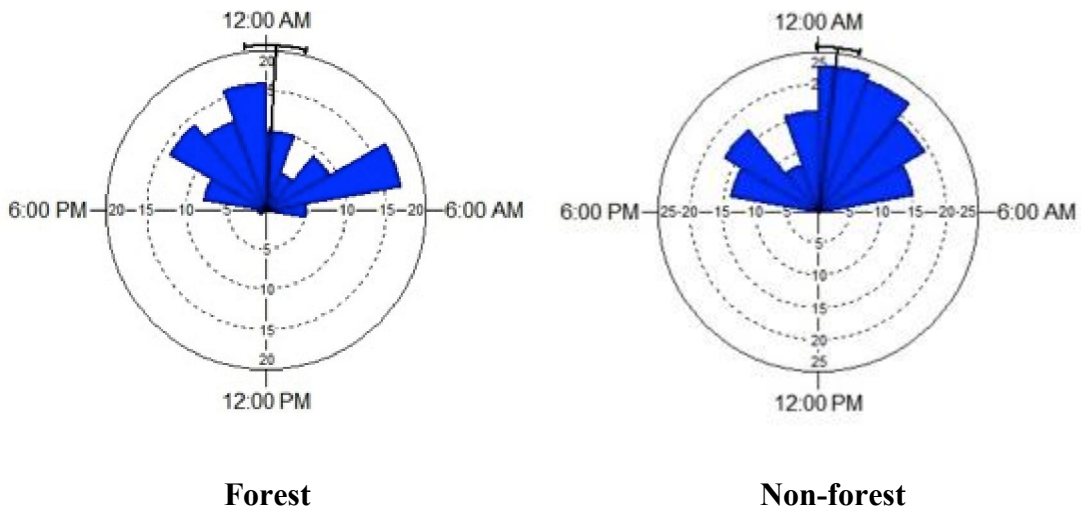


Figure 4.13: Temporal activity pattern of rodent, porcupines in natural habitats or forest and human-modified or non-forest habitats

<b>Variables</b>	<b>Watson U<sup>2</sup> test value</b>	<b>p value</b>
<b>Himalayan langur</b>	0.738	<0.001
<b>Macaque</b>	0.333	<0.005
<b>HMP civet</b>	0.032	>0.5
<b>Jungle cat</b>	*****	*****
<b>Leopard cat</b>	0.082	0.5>p>0.2
<b>Red fox</b>	0.041	>0.5
<b>YT marten</b>	0.071	>0.5
<b>Barking deer</b>	0.49	>0.5
<b>Goral</b>	*****	*****
<b>Sambar</b>	0.163	0.1>p>0.05
<b>Serow</b>	*****	*****
<b>Wild pig</b>	0.58	<0.001
<b>Porcupine</b>	0.378	<0.002
<b>Leopard</b>	0.088	0.5>p>0.2
<b>***** indicates that a result could not be calculated.</b>		

Table 4.3: Results of multi-sample circular statistics test (Watson U<sup>2</sup>) of temporal activity of wild mammals in Mandal river sub-basin showing significant differences in activity pattern in natural and human-modified areas (Natural= dry and moist forest, human-modified = secondary scrubland, mosaic, crop fields and settlement areas)

### 4.3 Species-habitat association and identification of drivers

Occupancy models with delta AIC value of less than 2.00 were considered as equivalent models and the site occupancy estimates were averaged and used to create maps using ArcMap 10.2 (**Figure 4.4, 4.5 and 4.6**). List of selected models and their respective AIC values are given in **Appendix 4(a)**. Influence of variables in selected models for each species are presented in the **Appendix 4(b)**.

Result of occupancy gave prediction values with each selected model which were then averaged and plotted on map to visualize occupancy of a grid in a better way. Different species had different covariates that better explained their presence in a particular grid. For example, for barking deer AIC value for model  $Z\_dem + z\_gherb + z\_cc + z\_shrub$  gave least AIC value (723.54, AIC weight 0.34) followed by model  $Z\_dem$  (AIC value 724.59, AIC weight= 0.20), which reveal that 34% of probability of barking deer presence were explained by elevation, grass and herb cover, canopy cover and shrub cover while 20% was explained by elevation **Appendix 4(a)**. However, variables with high standard errors show low influence of variable on occupancy of a species **Appendix 4(b)**.

## Primates

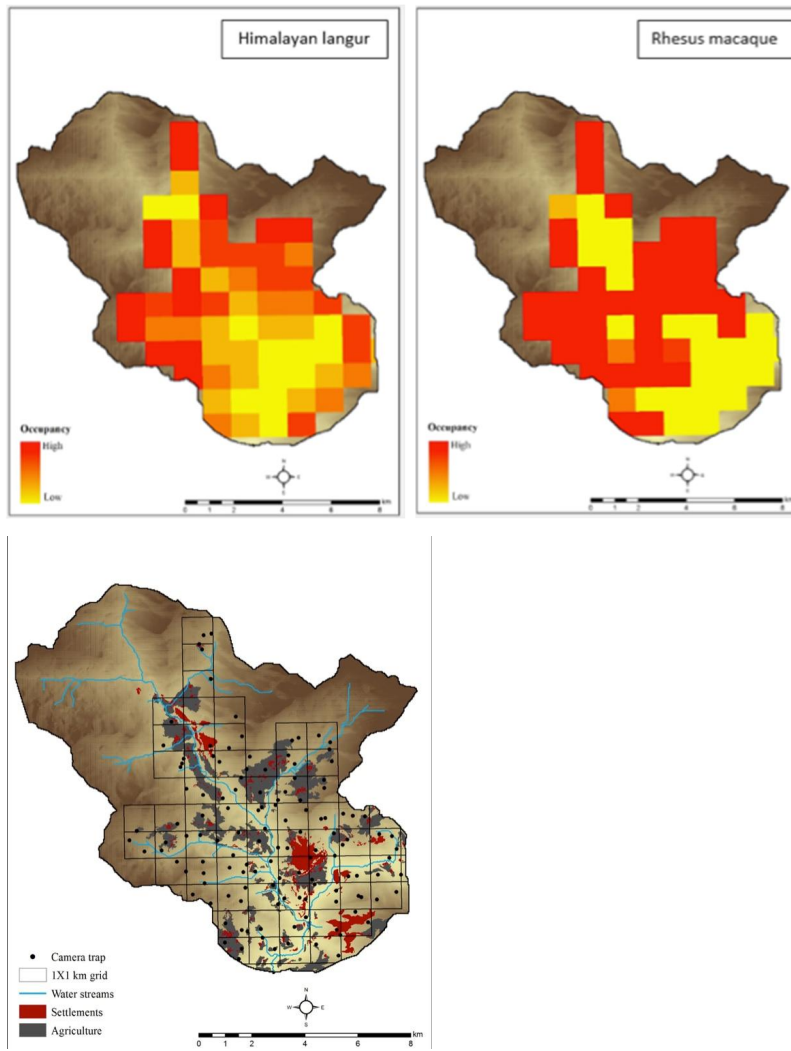


Figure 4.14: Maps showing occupancy of two primate species with the map of Mandal Sub basin to get comparative view according to habitat types in the grids, in Mandal Sub basin, Chamoli district, Uttarakhand, December 2016-April 2017

Both rhesus and langur were present all over the study area with rhesus macaque using some areas extensively while others quite less whereas langur uses areas with forested areas more than open areas. Rhesus macaques' occupancy was positively influenced by agriculture area ( $\beta = 1.08 \pm 0.35$ ). On the other hand, Himalayan langur did not show any significant relation with any co-variate.

## Large carnivore

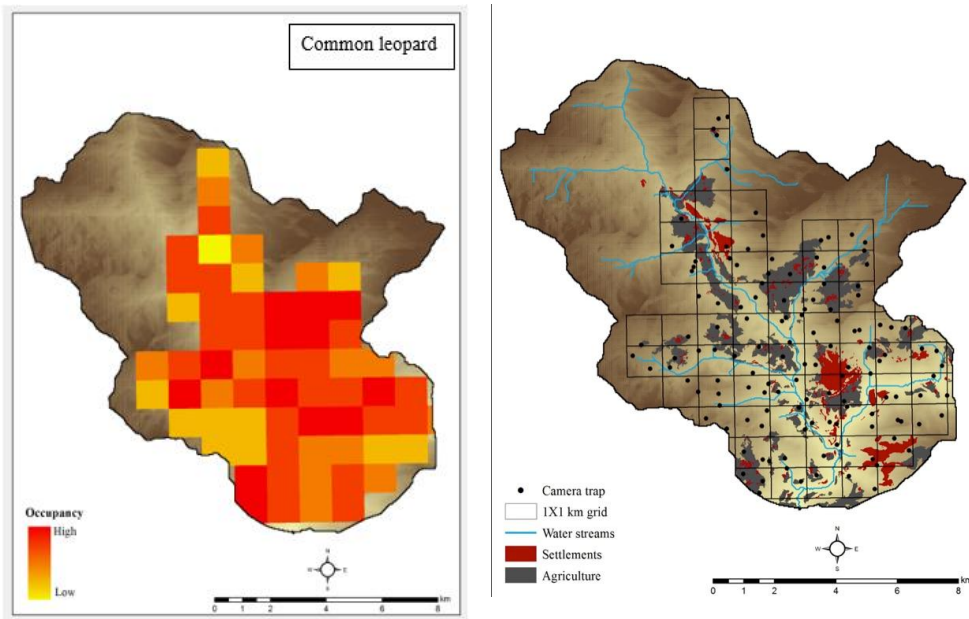
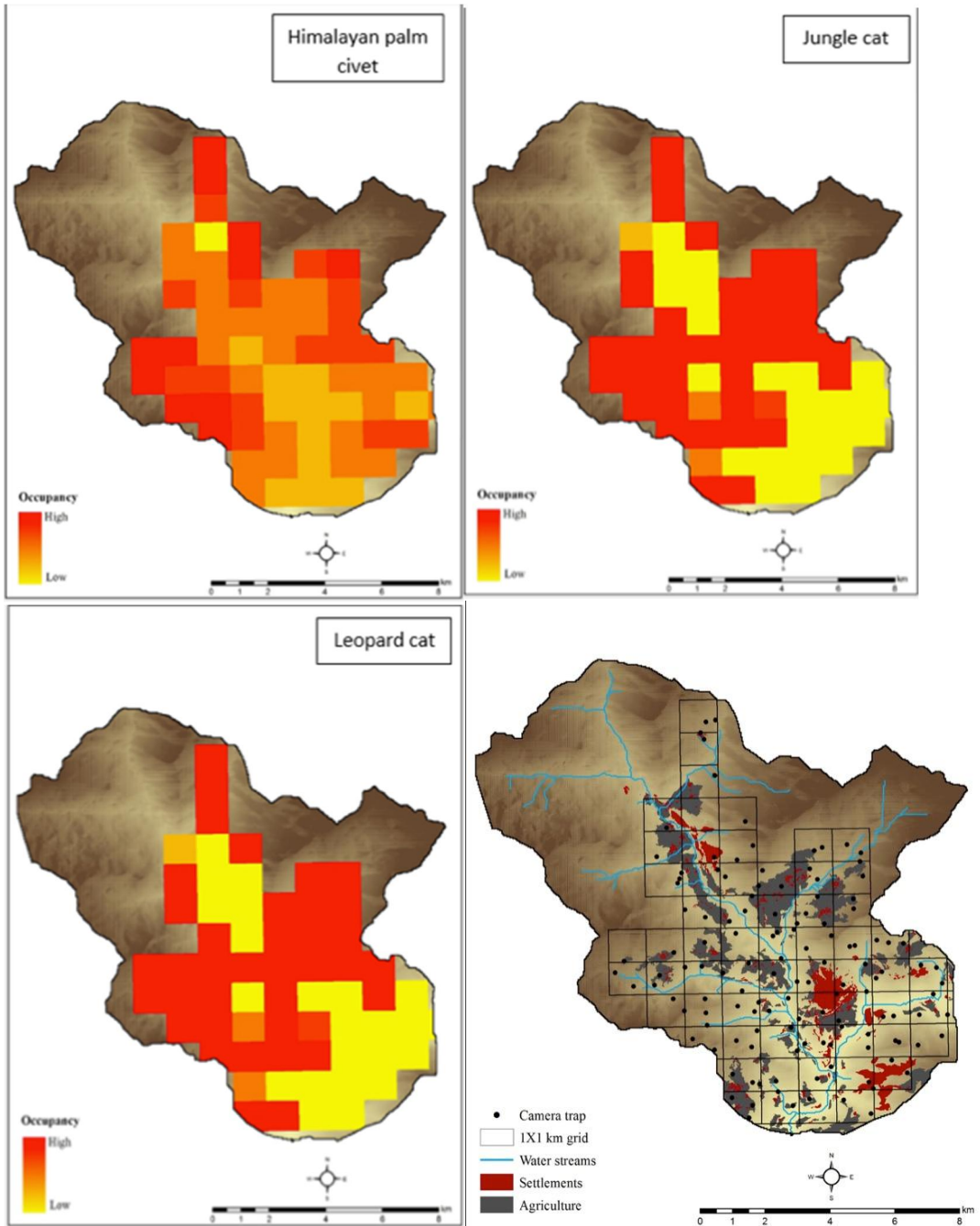


Figure 4.15: Maps showing occupancy of large carnivore with the map of Mandal Sub basin to get comparative view according to habitat types in the grids, in Mandal Sub basin, Chamoli district, Uttarakhand, December 2016-April 2017

As shown in **Appendix 4(b)**, leopard's occupancy was negatively influenced by distance to agriculture ( $\beta = -0.46 \pm 0.30$ ).

Small carnivores



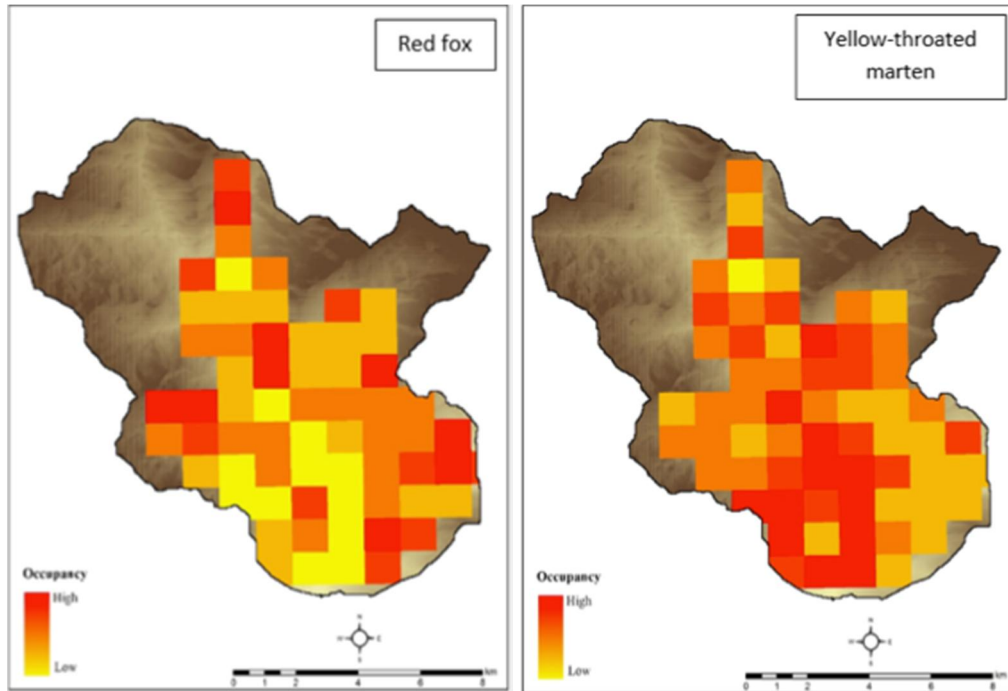


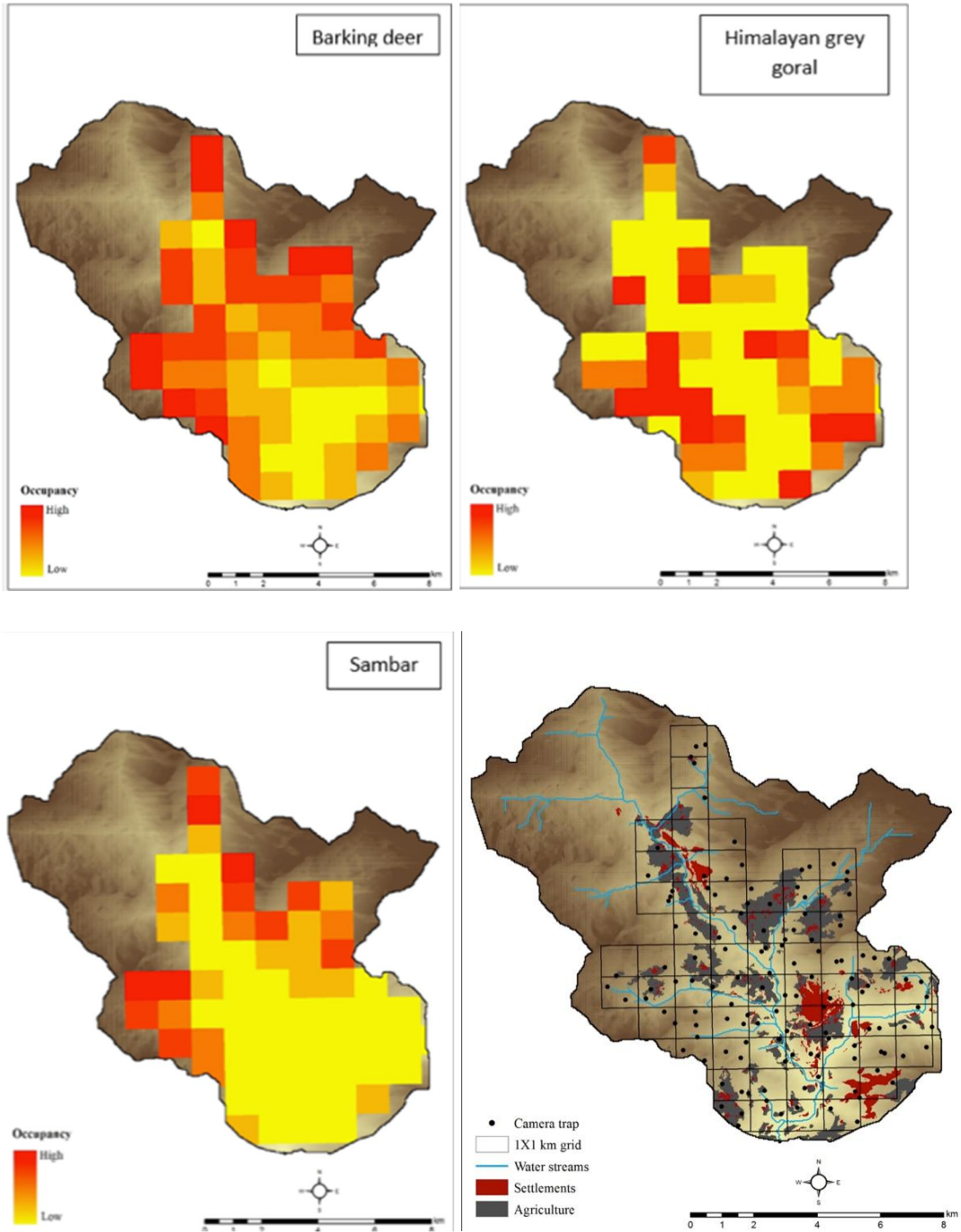
Figure 4.16: Maps showing occupancy of small carnivores with the map of Mandal Sub basin to get comparative view according to habitat types in the grids, in Mandal Sub basin, Chamoli district, Uttarakhand, December 2016-April 2017

Almost all carnivores occur all over the study area with varied intensity of usage pattern, except for leopard cat and jungle cat that were not present in low elevation zones of the study area.

Himalayan palm civet was positively influenced by elevation ( $\beta = 0.50 \pm 0.28$ ), while jungle cat's site occupancy was governed positively by presence of human in the grid ( $\beta = 1.09 \pm 0.48$ ) while negatively influenced by distance to agriculture ( $\beta = -4.51 \pm 1.99$ ) and area of human settlement ( $\beta = -1.12 \pm 0.55$ ). Leopard cat's site occupancy was positively influenced by area of agricultural fields ( $\beta = 71.45 \pm 67.79$ ), elevation ( $\beta = 72.45 \pm 70.33$ ), distance to human settlements ( $\beta = 167.06 \pm 157.14$ ) and human presence in the grid ( $\beta = 29.73 \pm 32.83$ ) while negatively influenced by distance to agricultural land ( $\beta = -87.38 \pm 82.26$ ). Red fox occupancy was negatively influenced by area of agriculture ( $\beta = -1.43 \pm 0.87$ ) and distance to agriculture ( $\beta = -0.73 \pm 0.51$ ). For yellow-

throated marten agriculture area ( $\beta = 0.50 \pm 0.28$ ) had positive influence on its occupancy.

### Ungulates



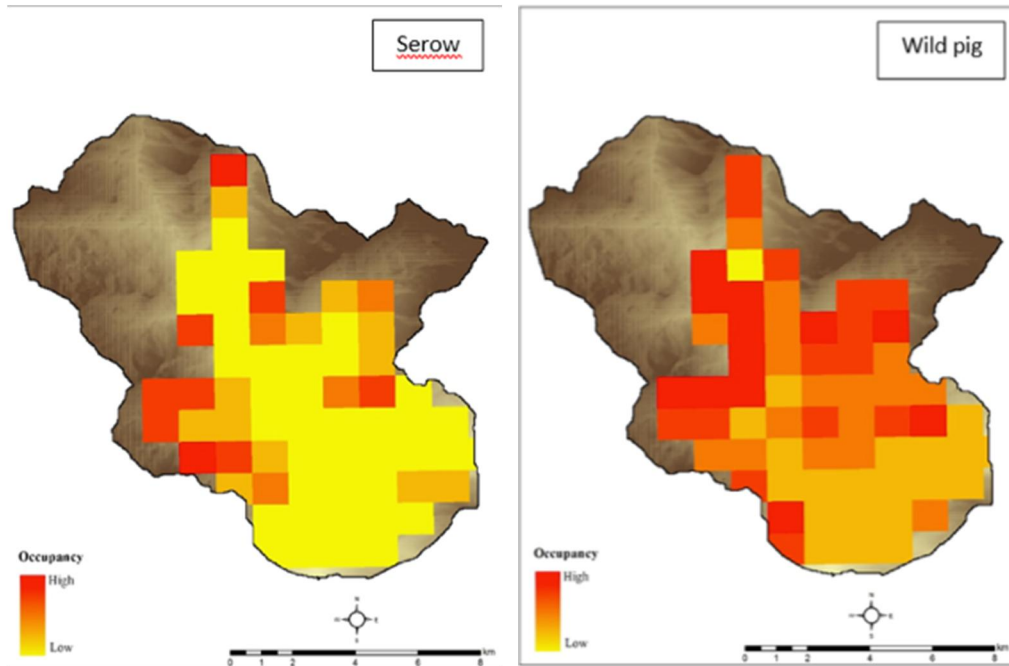


Figure 4.17: Maps showing occupancy of ungulates with the map of Mandal Sub basin to get comparative view according to habitat types in the grids, in Mandal Sub basin, Chamoli district, Uttarakhand, December 2016-April 2017

Barking deer was positively influenced by canopy cover ( $\beta = 0.30 \pm 0.11$ ), elevation ( $\beta = 0.61 \pm 0.23$ ) and shrub cover ( $\beta = 0.51 \pm 0.22$ ). However, goral on the other hand shows bit of restricted pattern with negatively influenced by elevation ( $\beta = -1.42 \pm 0.88$ ) and positively influenced by slope ( $\beta = 8.08 \pm 3.42$ ). Sambar negatively influenced by canopy cover ( $\beta = -0.83 \pm 0.43$ ), while positively influenced by elevation ( $\beta = 2.28 \pm 0.57$ ) and shrub cover ( $\beta = 0.77 \pm 0.41$ ). Serow being positively influenced by elevation ( $\beta = 1.36 \pm 0.77$ ) and slope ( $\beta = 3.09 \pm 1.62$ ). Wild pig's site occupancy was positively influenced by the area of human settlement ( $\beta = 0.48 \pm 0.24$ ).

## Rodent

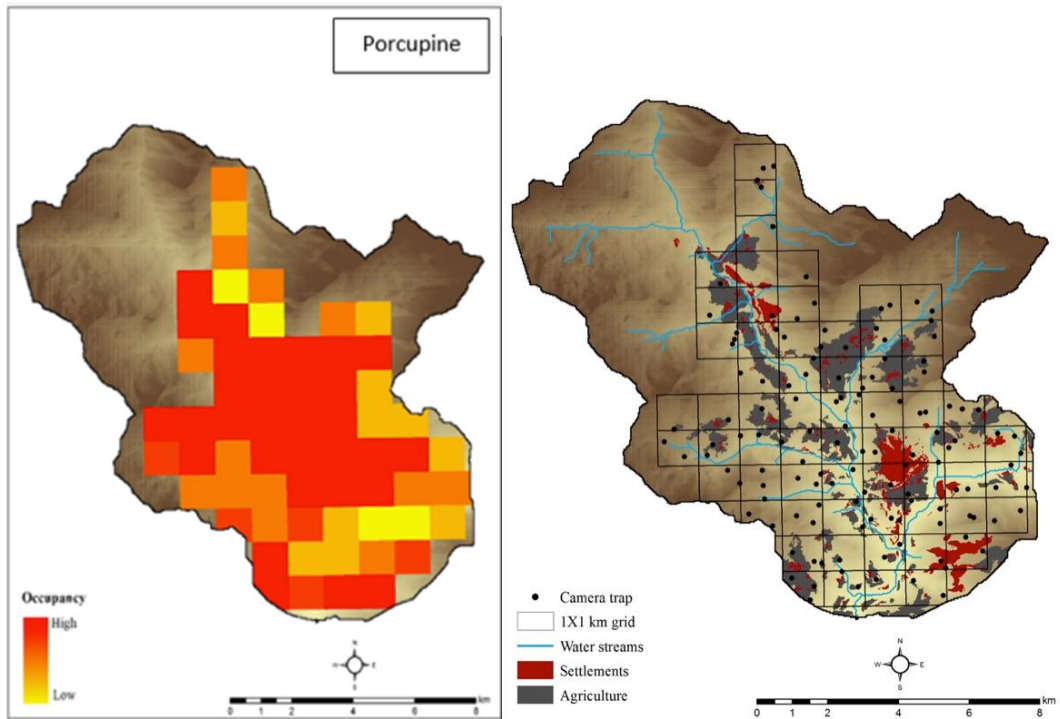


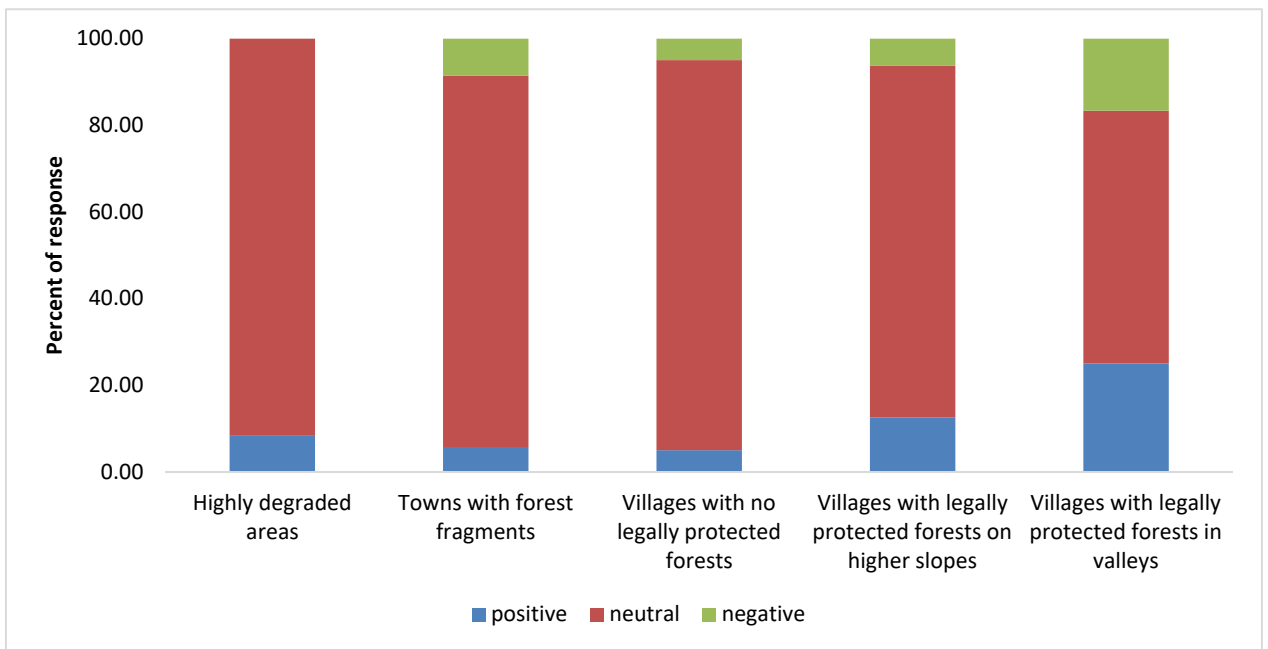
Figure 4.18: Maps showing occupancy of a rodent with land-use map of Mandal Sub basin to get comparative view according to habitat types in the grids, in Chamoli district, Uttarakhand, December 2016-April 2017

Porcupine's grid occupancy was positively influenced by presence of human in the grid ( $\beta = 1.10 \pm 0.48$ ) while negatively influenced by distance to agriculture ( $\beta = -4.51 \pm 1.99$ ) and area of human settlement ( $\beta = -1.12 \pm 0.55$ ).

#### 4.4 Peoples' perception

Based on the answers of individuals in villages of above mentioned areas, percent of people having different perception about wildlife has been depicted through stacked bar graphs. Majority of population expressed positive to neutral perspective to wild animals while most believed in conservation of wildlife. Refer to **Table 3.5** (Chapter 3) for abbreviations of villages used in text. Areas 1 to 5 are according to the serial order of villages in graphs.

- a) On perception to non-conflict/non-harmful wildlife (animals like leopard cat/ yellow-throated marten that do not harm directly in terms of depredation/crop damage or harm to human lives. People who considered them as threat replied



accordingly)

Figure 4.19: Stacked bar graphs representing peoples' perception on non-harmful species in five categorized areas in Mandal Sub basin, Chamoli district, Uttarakhand, December 2016-April 2017

Highly degraded areas had majority of population that had positive perception to non-conflict animals with little increase in the 3 areas, however, 12.5 percent of population in area 5 (VVF) perceived all animals to be threat.

b) On believe in co-existence with non-harmful animals

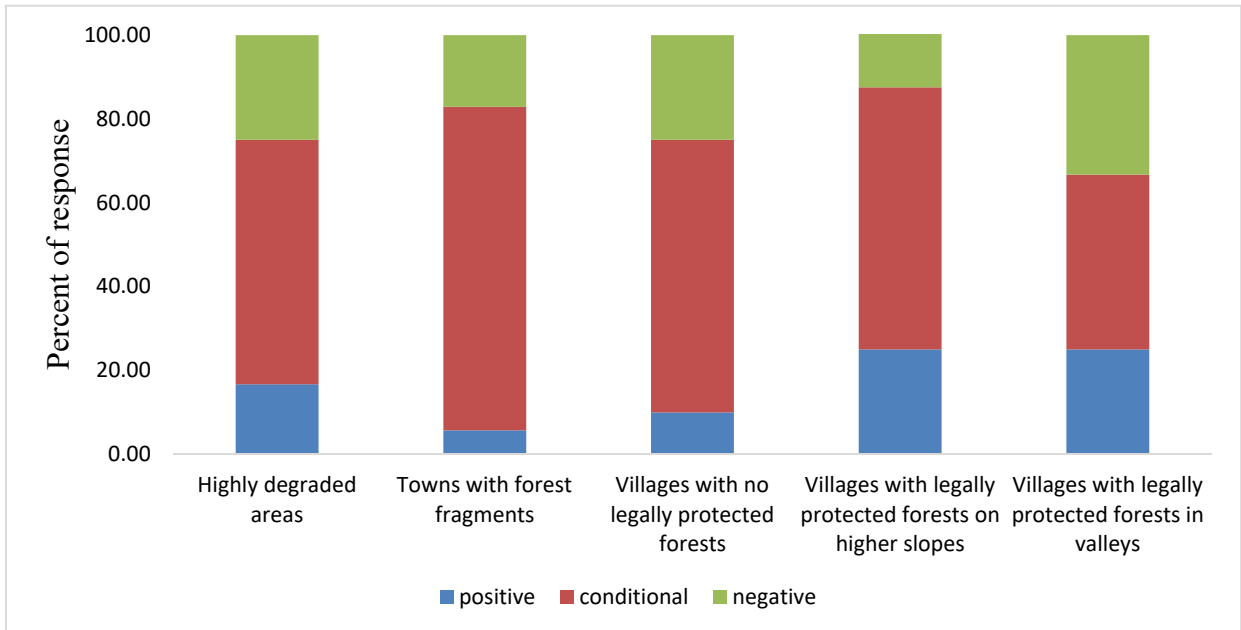


Figure 4.20: Stacked bar graphs representing peoples' perception on co-existence in five categorized areas in Mandal Sub basin, Chamoli district, Uttarakhand, December 2016-April 2017. Positive = Yes, conditional = if no harm caused, negative = no

In **Figure 4.20** though majority believed in co-existence in first three areas, villages that were closer to forest (area 4(VHS) and area 5(VVF)) showed increased trend of not believing in co-existence.

c) On benefits gained due to presence of wild animals

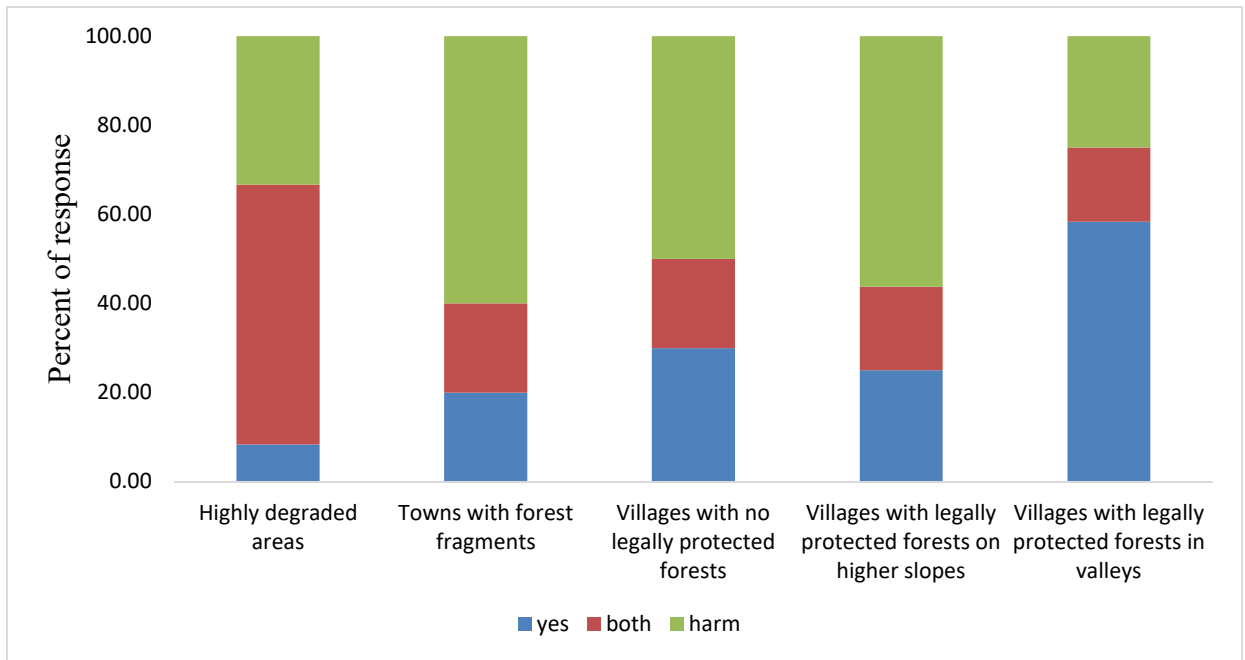


Figure 4.21: Stacked bar graphs representing peoples' perception on benefits gained due to presence of wild animals in five categorized areas in Mandal Sub basin, Chamoli district, Uttarakhand, December 2016-April 2017. Both = benefits as well as harm

**Figure 4.21** shows that 60 percent of population in area 2 (TSF) believed wild animals gave no benefit but were more of threat to them whereas, locals from all areas largely had negative connotations. Area 5 (VVF) had 58.33 percent people who believed in benefits from wild animals. Their idea of benefit from animals was *in sensu* their role in balance of nature.

d) On believe in conservation

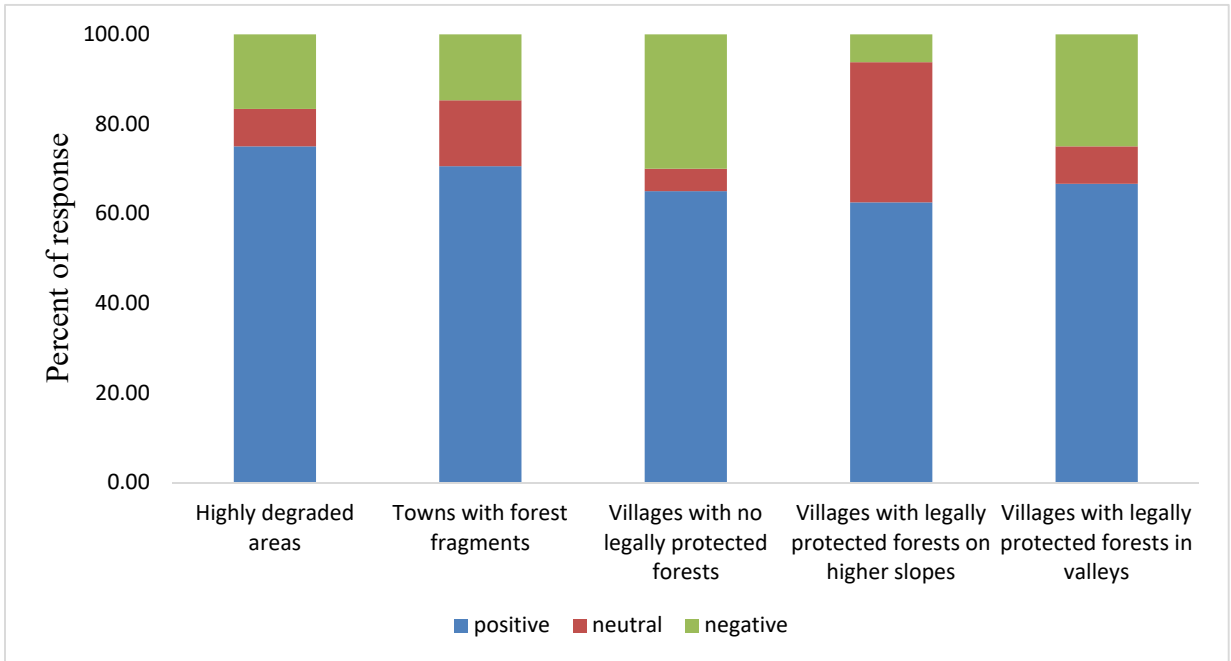


Figure 4.22: Stacked bar graphs representing peoples' perception on conservation of wildlife in five categorized areas in Mandal Sub basin, Chamoli district, Uttarakhand, December 2016-April 2017

Largely the villagers of all five areas believed in conservation of wild animals, however, except for area 4 (VHS), which has tourist route for Rudranath temple, a hindu shrine, had 6.25 percent of population that did not believe in conservation.

e) If animals get extinct and you don't see them anymore



Figure 4.23: Stacked bar graphs representing peoples' perception on the extinction of wild animals in five categorized areas in Mandal Sub basin, Chamoli district, Uttarakhand, December 2016-April 2017

While majority of population of areas 1, 2 and 4 expressed that they were happy if animals got extinct, area 5 had 66.67 percent of people who felt sad about the idea of not seeing these animals anymore.

f) Government measures against conflict animals

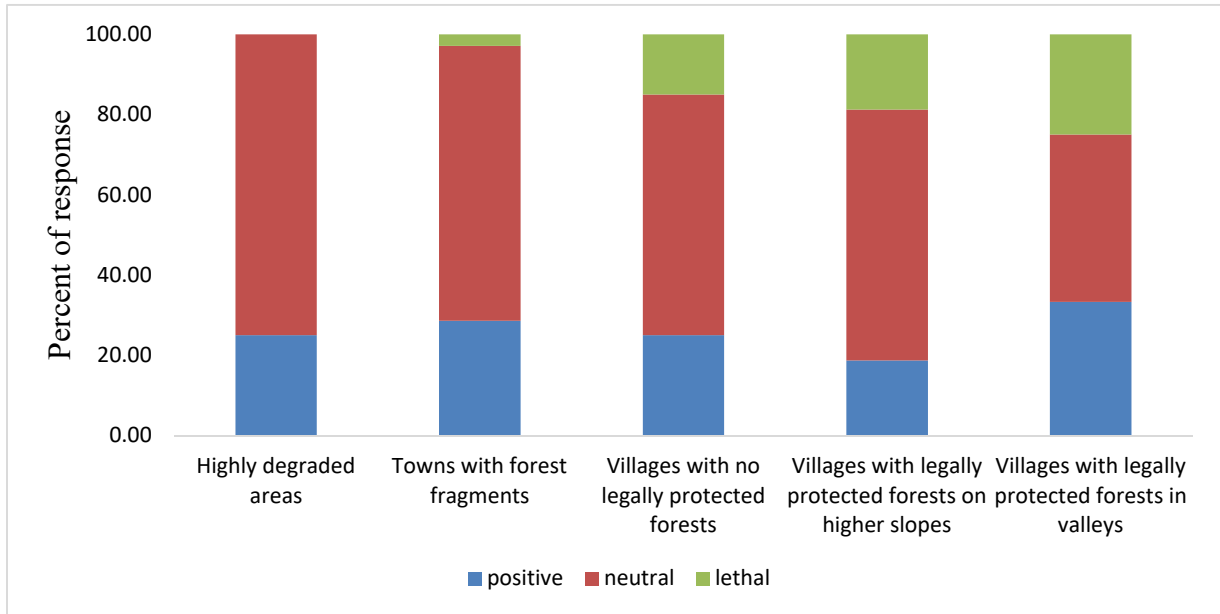


Figure 4.24: Stacked bar graphs representing peoples’ perception on measures that government should take for/against conflict animals in five categorized areas in Mandal Sub basin, Chamoli district, Uttarakhand, December 2016-April 2017

Except for areas 5, majority wanted a solution for wild animals in a way that would either be neutral or positive, however, 75 percent of people from area 5 believed in control or removal of animals and some with idea of killing conflict animals

g) Change in land use pattern for development of village

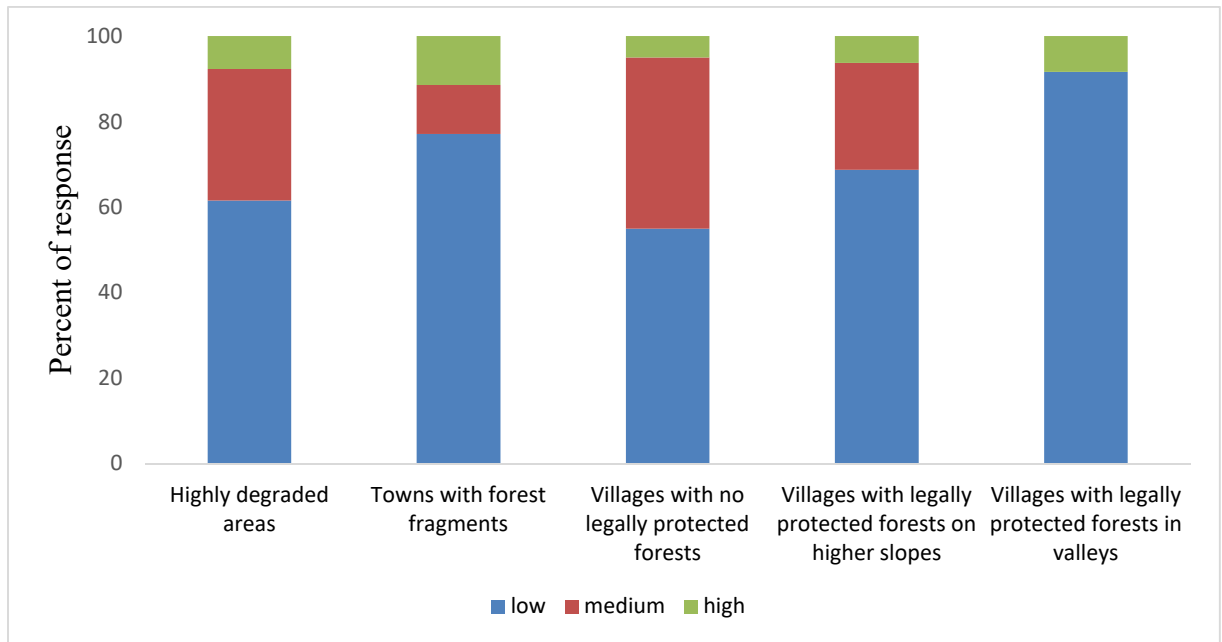


Figure 4.25: Stacked bar graphs representing perception of people on extent of change in land-use pattern for development in five categorized areas in Mandal Sub basin, Chamoli district, Uttarakhand, December 2016-April 2017

While almost all areas did not want development at the cost of their current land-use pattern, area 5 had exceptionally only 8.33 percent of people who agreed to large scale change in land-use pattern while 91.67 percent who asked for development possible with nature.

## CHAPTER 05

### DISCUSSION

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With increasing human population and development aspirations, much of the natural areas are becoming human-modified system (Wilcove et al. 1998) with direct as well indirect implications for biodiversity management. These systems are also important from management perspective since these areas attract specific animal species, often leading to human wildlife conflicts and causing negative response from people towards wildlife conservation ( Yom-tov et al. 1995, Baker 2007, and Oro et al. 2013). However, the perception that human modified system provide resource base for wild animals, specifically in the mountain system, is less understood (Pal et al. 2016). Many studies carried out in human-modified landscapes in India, have focused on small vertebrates (Elsen et al. 2016) and invertebrates with hardly any study on mammals in mountains (Osuri et al. 2010). To better manage such landscapes, a better understanding of usage pattern is required both for conservation and effectively managing negative interactions between humans and synanthropic animals.

#### 5.1 Spatial usage

Although majority of the species seemed to be using human modified areas there was a trend in terms of usage in space and time. Ungulates seem to be avoiding areas near settlement which could be an artifact of 1) their dietary patterns i.e. being herbivores they would not need to come near settlement for resources, 2) anthropogenic pressure, presence of humans as well as dogs, their predator, which were captured most near settlements and 3) possibility of getting poached, although species are protected under WPA, hunting for meat still exists in some villages in the study area (pers. obs.). Also, based on their behavioural plasticity as suggested by Lowry and Wong (2013), who also reported species with greater behavioural plasticity have greater success in such areas.

Interestingly, within ungulates, species that use crop fields, mostly for resources (crops) were also captured in mosaic and/or secondary scrubland. Whereas species such as goral and serow did not seem to be using areas with high human mediated disturbance. Such

pattern of avoiding human mediated disturbance in Bhattacharya et al. (2012) where these animals seemed to be avoiding tourist trails in Khangchendzonga Biosphere Reserve, Sikkim. Goral was visually encountered twice in grass fields made for cows but always were very close to forests. However natural forests seemed to be used by all ungulates. Sambar had high capture rates in crop fields compared to forests because they would use crop fields for few hours and passed by in front of the strategically placed camera traps. However similar detection history was not found in moist forests for sambar as the movement of the species in moist forest is not governed by any particular factor.

Small mammals seemed to be using almost all habitats however, species such as jungle cat, red fox and Himalayan masked palm civet showed high dependencies on crop fields could be because of their diet and/or type of habitat they prefer (Johnsingh and Manjrekar 2012). While Himalayan masked palm civet and red fox used both natural forests as well as crop fields, they too showed more preference to crop fields. Rodents being one of the major pests in crop fields (Stenseth et al. 2003), most of these small carnivores were expected to come for them. Other species such as leopard cat and yellow-throated marten seemed to be using habitats including near settlement areas but also mostly relying on natural forests. This was contrary to what Prater (1965) mentioned that yellow throated marten avoid human. However, extent of human habitations Prater (1965) mentions is not clear in the text. Red fox seemed to be avoiding areas where dog captures were the highest (secondary scrubland mean photo-capture for dog =  $36.18 \pm 35.26$  and near human settlement =  $117.57 \pm 108.20$ ). Hence, presence of dog seemed to be a limiting factor for red fox which is justified by the fact as dog is a direct competitor as well as a predator of red fox. Porcupine, a rodent, was the most common wild animal in study area using all the habitats proportionately and being nocturnal can avoid human presence directly. Studies done elsewhere have found similar results for small carnivores which are generally omnivore (Fedriani et al. 2001, Fuller et al. 2010 and Gehrt 2014) which are also reported to be tolerant to human mediated disturbance (Doncaster and Macdonald 1991, Tigas et al. 2002). Small and large carnivore species like the red fox (*Vulpes vulpes*) (Gloor et al. 2002, Contesse et al. 2004, Ditchkoff et al. 2006, Baker et al. 2007, Ghoshal et al. 2015), Coyotes (*Canis latrans*) (Mcclure et al. 1995 and Fedriani et al.

2001), spotted hyena (*Crocuta crocuta*) (Abay et al. 2011), golden jackals (*Canis aureus*) (Macdonald 1979), (Yom-tov et al. 1995), Australian dingo (*Canis lupus dingo*) (Newsome et al. 2014) were found to have dependency on anthropogenic subsidies avoiding human disturbance.

The large carnivore, leopard used secondary scrubland and mosaic more than other natural and non-natural habitats for prey being a limiting factor. Most crop dependent ungulates as well as domestic animals were found in both of these areas proportionately hence such trend of usage by leopard is possible. A buffalo calf was found neatly hidden in a lantana bush below the town Gopeshwar. This was an area occasionally used by people.

Jackal that was once common in these areas in the early 1990s (S. Sathyakumar *pers. comm.*) is clearly on the decline in these areas as reported by people and as evident from the poor photo captures. The possible reasons could be increase in dog populations and changing land use practices but it could also be an artifact of other reasons not known to scientific community as decline in populations of jackal is being observed in many areas (Pillay et al. 2011).

Primates, both langur and macaque showed affinity with crop fields and near settlement areas. One being frugivorous while other a folivorous, showed similar usage patterns. Langurs being photo captured as well as observed directly in forests whereas rhesus macaques having adapted to human lifestyle all over India (Southwick and Siddiqi 1994), showed less dependencies to forests except for roosting.

## **5.2 Temporal pattern**

Most of the diurnal species did not show much difference in temporal activity pattern as would be expected, because these species have probably adapted to live with humans since hundreds of years. They might not avoid humans temporally but do it spatially as mentioned above. However, some species showed differences in activity patterns such as langurs and macaques. This could be the case not to avoid humans per se but to exploit food resources that are present in non-forest areas. Since roosting sites are mostly in adjacent forest patches, morning and evening activities are more in forest.

Activity of wild pig in non-forest areas was found to be clumped within short range of time while in forested habitat it seems to be using all through the night. Similar pattern is also mentioned in Prater (1965) where it was mentioned that normally they feed in early morning and late night while in disturbed areas its chiefly in night. Such narrow range of temporal activity is also observed in leopard cat where peak activity period in non-forest areas are from 12 am to 3 am while in forested areas it is active throughout the night and early morning. In case of yellow throated marten, species was active during day time while in forest it seems to follow crepuscular pattern with minimum activity in the day time. There was no information found on the temporal activity pattern to relate to.

Interestingly, barking deer that shares the same activity patterns in space and time with human showed least difference between the two types of habitats. This points out to possibility of animal getting adapted to human presence by just flushing off if a sudden encounter with human happens and not shifting temporal activity in both habitats. Sighting barking deer and goral were the most common encounters during present study period.

Hence it seems both spatial and temporal patterns govern the possibility for wild animals to exploit or use human modified areas for different purposes. Availability of easier food resources, complying with optimal foraging theory along with cover seems to be governing the usage of human-modified area by wild animals.

### **5.3 Drivers**

The results of species-habitat association found some interesting patterns which also support the results of spatial and temporal patterns. Generalists and omnivores such as small carnivores (Prater 1965) are mostly omni-present except where no natural distribution is found. These results also comply with other studies done across the globe where small carnivores have been found to be least affected by the human presence (Tigas et al. 2002).

Capture rates of leopard could be underestimated as the species is territorial with large home ranges. However, it interestingly was found all over the region which also points out to the exceptional adaptation this species of large cat has (Athreya et al. 2016).

Leopard scats were found almost in every grid and even close to town and cases of depredation on dogs from balconies or even door steps of people are common (*pers. obv.*). Ungulates avoided areas with high human disturbance which was contrary to a study done in San Diego (Nicholls et al. 2008) where Mule deer was found to be fairly adaptable to urbanization. However, use of areas such as crop fields, mosaic areas and secondary scrub land was common for most of the species except goral and serow that seem to be rather specialists in this study. This pattern as mentioned above was similar to a study by Bhattacharya et al. (2012) where goral and serow seemed to be avoiding tourist trails within Khangchendzonga Biosphere Reserve, Sikkim. Such usage pattern complies with species ecology as the basic requirement of food (grass and herb cover), cover (shrub cover to conceal from human presence in disturbed areas) and habitat (canopy cover and elevation) is explained for this small solitary forest ruminant.

Two primate species had a difference in usage as one (rhesus macaque) is more of an exploiter, occurs in high abundance wherever present. This also points on to restricted ranging patterns with few troops acquiring their resource abundant areas. Himalayan langur seems to be not restricted to some patch of resource abundant sites.

Hence, most of the wild mammals are present and seemed to have adapted to human-modified landscapes and probably are using both natural as well as non-natural areas in a similar fashion. A study carried out in Western Ghats evaluated mammalian species in a similar way (Sridhar et al. 2008) where they found similar densities of animals between protected and unprotected plantation matrix with more abundance of primates in private lands, although field methods used were different from present study.

#### **5.4 Peoples' perception**

As the intensity of proportion of forest increases, negative response towards wildlife increases which could be the result of increased intensity in conflicts. Area 1 (HDA) being the most degraded land with least abundance and diversity of animals, shows positive response to most of the questions asked. However, the most important aspect of conservation and their feelings if the animals got extinct was most positively related to villages with legally protected areas in valleys where they face more conflict by wild

animals than other areas but being more close to nature brings them to a feel of being more connected to wild animals. Hence, forests are not only important for wildlife but also for people to relate to them and have empathy for their wild neighbours.

Taking into consideration the perception of the people living in such landscapes, the Government of Uttarakhand will have to develop and implement small, sustainable and socially responsible land use plans to ensure the maintenance of the current delicate balance and co-existence of humans and wildlife. Any large-scale development project (“Uttarakhand Vision 2020”) in areas such as Mandal sub basin would be detrimental to relatively peaceful co-existence of humans and wildlife.

With people believing in conservation and co-existence (if not much harm is caused), possibility of concept of conserving wild animals in human modified landscapes seems to be practical if provided with better management plans and involving locals in conservation in a way that benefits them directly, mostly through employment which is a major factor influencing lives of people in Garhwal.

This study was not able to point onto specific resources per se for different wild mammals but based on previous studies, patterns visualized through present study and data available on diet preferences done elsewhere, some of the drivers were speculated.

Hence there is a need to focus on such synanthropic species to fill in research gaps based on their ecology and behavioural adaptations in mountainous human dominated areas. Some of the interesting findings are mentioned in (**Appendix 4**).

## CHAPTER 06

### CONCLUSION

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All carnivores and barking deer, sambar, wild pig and porcupine from my data appear to be ‘urban adapters’ which not necessarily are omnivorous in diet as mentioned by Croci and Clergeau 2008 and Gehrt 2014. While both primates seemed to be ‘urban exploiters’ which exploit human resources even in the presence of humans (based on questionnaire surveys, camera trap data and personal observations) as suggested by Kark et al. 2007. While goral and serow as ‘urban avoiders’ that avoided human modified areas, as suggested by Croci and Clergeau 2008.

Species like common leopard, jungle cat, leopard cat, red fox, yellow-throated marten, wild pig and porcupine seemed to be well adapted to live near human modified areas. However, intensification in land-use change towards urbanization would be threat to even these species as these might show positive influence by some of the anthropogenic factors like distance or area of agriculture or settlement but all these species are also negatively influenced by area of settlement or positively influenced by distance to settlements. However, other species like barking deer, sambar, serow and goral would be the first to be affected by high intensity urbanization. With majority of human individuals do not want high intensity development that would deplete their forests, a major source of their livelihood, there is a scope of conserving human-modified landscapes along with natural forests to sustain wildlife such areas. However, without proper awareness and management schemes, it would be an impossible task to do.

All the target wild mammal species more or less seemed to have adapted spatio-temporally to avoid human presence directly or indirectly.

Although the study area has 3 major tourist spots (Tungnath, Rudranath and Anusuya temple), local people do not get much benefit from the eco-tourism (from information collected during questionnaire survey). Employment being a major crisis in Garhwal, probably eco-tourism or other nature conservation related employment to local community might help both human as well as wild animals. This was also asked from

local villagers and approximately 50% of the interviewed people had willingness of working with forest department or for conservation (of plants/animals) provided they get employed for the same. However, management of wild animals would still have to be a major concern to maintain balance in such areas.

There is an urgent need to focus on such synanthropic species to fill in research gaps based on their ecology and behavioural adaptations and long-term studies in mountainous human dominated areas to understand these landscapes and manage them in a better way.

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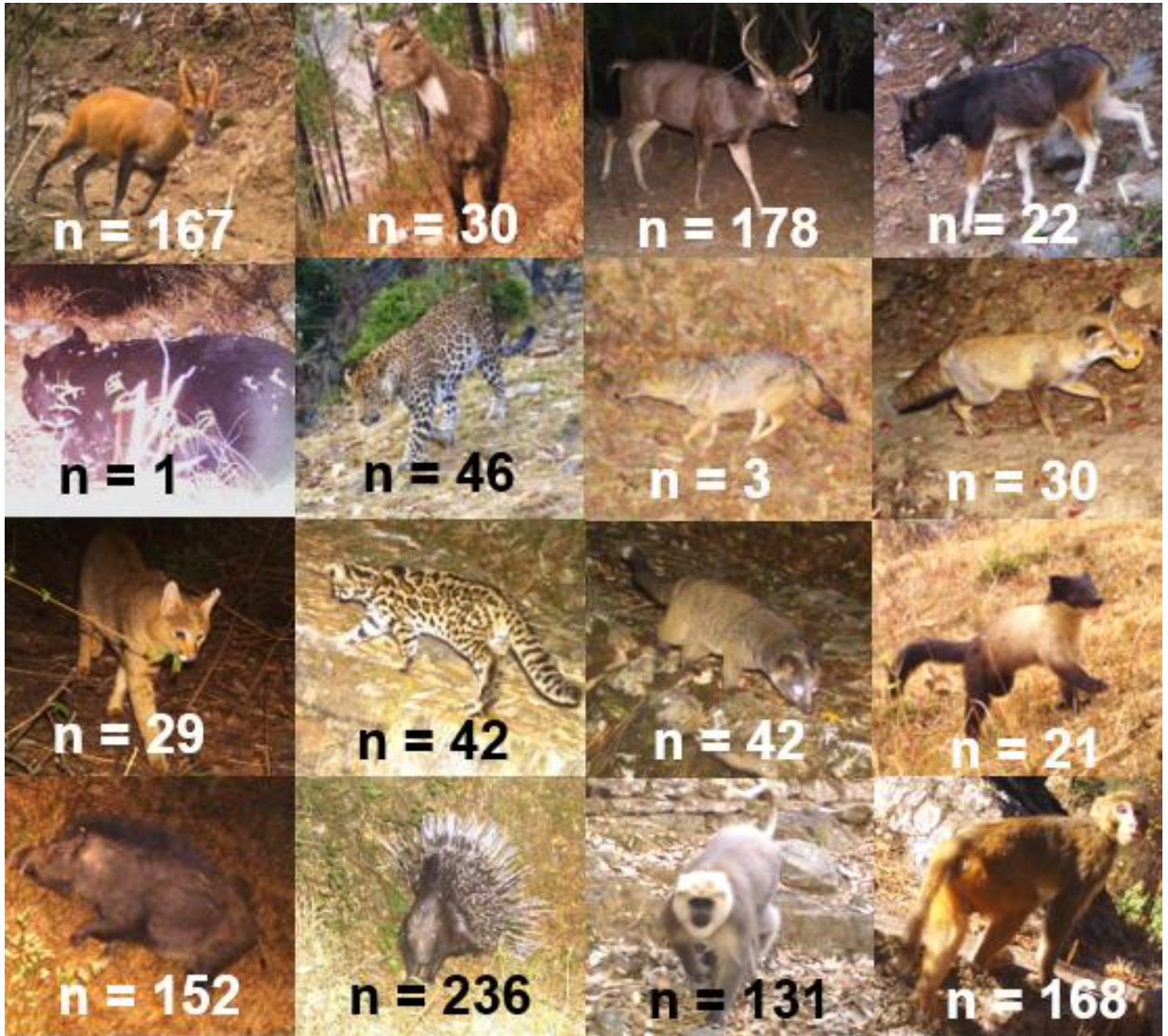
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## APPENDICES

Appendix 1: Species captured in camera traps with number of times captured within study period of January 2017 to April 2017 present within the study area



List of domestic and wild animals captured during study period:

a. Wild animals

<b>Common name</b>	<b>Scientific name</b>	<b>IUCN red list category</b>
Asiatic black bear	<i>Ursus thibetanus</i>	Vulnerable
Barking deer	<i>Muntiacus vaginalis</i>	Least concern
Common leopard	<i>Panthera pardus</i>	Vulnerable
Golden Jackal	<i>Canis aureus</i>	Least concern
Himalayan grey goral	<i>Nemorhaedus goral bedfordi</i>	Data deficient
Himalayan langur	<i>Semnopithecus schistaceus</i>	Least concern
Himalayan masked palm civet	<i>Paguma larvata</i>	Least concern
Indian crested porcupine	<i>Hystrix indica</i>	Least concern
Jungle cat	<i>Felis chaus</i>	Least concern
Leopard cat	<i>Prionailurus bengalensis</i>	Least concern
Red fox	<i>Vulpes vulpes</i>	Least concern
Rhesus macaque	<i>Macaca mulatta</i>	Least concern
Sambar	<i>Rusa unicolor</i>	Vulnerable
Himalayan Serow	<i>Capricornis thar</i>	Near threatened
Wild pig	<i>Sus scrofa</i>	Least concern
Yellow throated marten	<i>Martes flavigula</i>	Least concern

b. Domestic animals and human

Common name	Scientific name
Buffalo	<i>Bubalus bubalis</i>
Cow	<i>Bos taurus</i>
Domestic cat	<i>Felis catus</i>
Domestic dog	<i>Canis lupus familiaris</i>
Domestic pig	<i>Sus scrofa domesticus</i>
Horse	<i>Equus caballus</i>
Human	<i>Homo sapiens sapiens</i>
Mule	<i>Equus asinus X Equus caballus</i>

Appendix 2: Mean and standard error of average camera trap photo captures per 100 trap nights. (ns: near settlement; cf: crop field; mo: mosaic of forest and crop fields; ss: secondary scrubland; df: dry forest; mf: moist forest)

Habitat	Barking deer		Domestic cat		Domestic pig		Domestic dog		Goral		HMP civet	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
ns	0.00	0.00	0.51	0.51	7.41	7.41	117.51	108.20	0.00	0.00	0.85	0.85
cf	4.04	1.71	0.00	0.00	0.00	0.00	12.64	7.31	1.68	1.68	6.09	4.13
mo	22.40	11.64	0.00	0.00	0.00	0.00	9.75	7.30	0.00	0.00	2.21	1.30
ss	9.73	6.73	0.00	0.00	0.00	0.00	36.18	35.26	0.00	0.00	0.62	0.62
df	3.37	1.60	0.00	0.00	0.00	0.00	2.50	1.52	3.45	1.07	0.13	0.13
mf	10.10	2.79	0.00	0.00	0.29	0.29	10.95	3.83	2.30	0.90	4.60	3.78
Habitat	Human		Jackal		Jungle cat		Langur		Leopard		Livestock	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
ns	178.49	76.05	0.85	0.85	1.53	1.05	24.36	16.78	0.76	0.55	14.96	6.89
cf	381.16	240.54	0.53	0.53	9.45	4.97	7.10	5.49	0.53	0.53	185.98	158.92
mo	358.21	201.81	0.00	0.00	1.21	0.85	2.53	1.18	3.71	1.69	23.93	9.95
ss	261.01	162.55	0.00	0.00	1.42	1.04	0.00	0.00	6.77	4.15	25.98	19.54
df	85.18	26.84	0.00	0.00	0.00	0.00	4.23	3.23	1.88	1.31	3.69	2.58
mf	201.12	49.06	0.00	0.00	0.14	0.14	5.25	2.02	3.16	1.17	19.56	5.51
Habitat	Leopard cat		Macaque		Porcupine		Red fox		Sambar		Serow	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
ns	3.63	3.33	34.50	15.66	7.67	3.42	0.00	0.00	0.00	0.00	0.00	0.00
cf	1.43	1.00	7.79	5.27	9.51	3.77	2.06	1.43	61.74	29.01	1.68	1.68
mo	0.77	0.77	2.31	1.59	20.44	7.05	2.07	1.82	12.36	9.99	0.00	0.00
ss	2.74	1.44	36.68	31.51	20.90	8.70	0.00	0.00	0.00	0.00	0.00	0.00
df	4.07	3.34	0.96	0.96	13.85	6.94	1.26	0.68	0.32	0.32	0.46	0.46
mf	2.10	0.75	0.75	0.53	9.31	2.25	2.12	1.32	6.63	3.68	2.29	1.66
Habitat	Domestic sheep		Wild pig		HYT marten							
	Mean	S.E.	Mean	S.E.	Mean	S.E.						
ns	1.28	1.28	1.57	1.30	0.98	0.68						
cf	0.00	0.00	20.58	17.90	0.49	0.49						
mo	30.78	15.13	24.39	14.82	0.74	0.51						
ss	3.27	3.27	5.09	2.57	0.44	0.44						
df	17.26	12.66	4.32	2.76	0.35	0.35						
mf	35.29	9.30	6.16	2.94	1.98	0.94						

Appendix 3: List of models with AIC values, delta AIC values and weight (a.) and coefficients representing the effect of different habitat characters on the occupancy of different species (b.)

Himalayan langur

a.

Model	AIC	Delta	AICwt
~1 ~ Z_dem + Z_dist_sett + Z_dist_agri + Z_set_area + z_shrub + z_human + z_dom + Z_agr_area	306.7232	0	0.784088

b.

Covariates	$\beta$	S.E.
p(Int)	-3.46239	0.179705
psi(Int)	-49.1612	43.82035
psi(Z_agr_area)	-379.634	385.3155
psi(z_cc)	NA	NA
psi(Z_dem)	72.11768	74.02925
psi(Z_dist_agri)	-12.9939	18.36096
psi(Z_dist_sett)	-40.2484	44.69678
psi(z_dom)	-26.6704	29.36201
psi(z_gherb)	NA	NA
psi(z_human)	269.7086	333.6084
psi(Z_set_area)	74.90386	83.16922
psi(z_shrub)	66.23694	73.84164
psi(Z_slope)	NA	NA
psi(z_tree)	NA	NA

Rhesus macaque

a.

Model	AIC	Delta	AICwt
~1 ~ Z_agr_area	402.4293	0	0.433382
~1 ~ Z_dist_agri + Z_agr_area + z_shrub	404.3052	1.875849	0.169643
~1 ~ Z_dist_agri + Z_agr_area	404.3129	1.883587	0.168988

b.

Covariates	$\beta$	S.E.
p(Int)	-1.99	0.17
psi(Int)	-1.55	0.30
psi(Z_agr_area)	1.08	0.35
psi(z_cc)	NA	NA
psi(Z_dem)	NA	NA
psi(Z_dist_agri)	NA	NA
psi(Z_dist_sett)	NA	NA
psi(z_dom)	NA	NA
psi(z_gherb)	NA	NA
psi(z_human)	NA	NA
psi(Z_set_area)	NA	NA
psi(z_shrub)	NA	NA
psi(Z_slope)	NA	NA
psi(z_tree)	NA	NA

Barking deer (BD)

a.

Model	AIC	Delta value	AICwt
~1 ~ Z_dem + z_gherb + z_cc + z_shrub	723.5344	0	0.340882
~1 ~ Z_dem	724.5952	1.06082	0.200563

b.

Covariates	$\beta$	SE
p(Int)	-1.6599	0.114512
psi(Int)	-0.84523	0.232089
psi(Z_agr_area)	NA	NA
psi(z_cc)	0.304493	0.217664
psi(Z_dem)	0.60712	0.234841
psi(Z_dist_agri)	NA	NA
psi(Z_dist_sett)	NA	NA
psi(z_dom)	NA	NA
psi(z_gherb)	0.044623	0.231042
psi(z_human)	NA	NA
psi(Z_set_area)	NA	NA
psi(z_shrub)	0.505105	0.222957
psi(Z_slope)	NA	NA

Goral (gor)

a.

Model	AIC	Delta value	AICwt
~1 ~ Z_dem + Z_slope	237.4468	0	0.315806
~1 ~ Z_dem + Z_slope + z_gherb + z_cc + z_shrub	237.9943	0.547472	0.240181
~1 ~ Z_dem + Z_dist_sett + Z_dist_agri + Z_set_area + z_shrub + z_human + z_cc + z_dom + Z_slope + z_gherb + Z_agr_area	238.5278	1.081011	0.183942
~1 ~ Z_dem + Z_slope + z_gherb + z_cc	239.0083	1.561561	0.144654

b.

Co-variate	$\beta$	SE
p(Int)	-3.0071	0.252278
psi(Int)	-4.46634	1.635707
psi(Z_agr_area)	NA	
psi(z_cc)	NA	
psi(Z_dem)	-1.41565	0.887025
psi(Z_dist_agri)	NA	
psi(Z_dist_sett)	NA	
psi(z_dom)	NA	
psi(z_gherb)	NA	
psi(z_human)	NA	
psi(Z_set_area)	NA	
psi(z_shrub)	NA	
psi(Z_slope)	8.083368	3.422119

Sambar

Model	AIC	Delta value	AICwt
~1 ~ Z_dem + z_cc + z_shrub	304.4969	0	0.425718
~1 ~ Z_dem + z_cc + z_shrub + z_gherb	305.7799	1.282991	0.224143

b.

Covariates	$\beta$	SE
p(Int)	-1.25646	0.167489
psi(Int)	-3.387	0.688491
psi(Z_agr_area)	NA	NA

Covariates	$\beta$	SE
psi(z_cc)	-0.82601	0.430894
psi(Z_dem)	2.28144	0.574519
psi(Z_dist_agri)	NA	NA
psi(Z_dist_sett)	NA	NA
psi(z_dom)	NA	NA
psi(z_gherb)	NA	NA
psi(z_human)	NA	NA
psi(Z_set_area)	NA	NA
psi(z_shrub)	0.776511	0.406822
psi(Z_slope)	NA	NA
psi(z_tree)	NA	NA

Serow (ser)

a.

Model	AIC	Delta value	AICwt
~1 ~ Z_dem + Z_slope	122.8703	0	0.387346
~1 ~ Z_dem + z_cc + z_gherb + Z_slope	124.2649	1.394597	0.192871

b.

Covariates	$\beta$	SE
p(Int)	-2.74723	0.415621
psi(Int)	-4.88035	1.626951
psi(Z_agr_area)	NA	NA
psi(z_cc)	NA	NA
psi(Z_dem)	1.361865	0.778533
psi(Z_dist_agri)	NA	NA
psi(Z_dist_sett)	NA	NA
psi(z_dom)	NA	NA
psi(z_gherb)	NA	NA
psi(z_human)	NA	NA
psi(Z_set_area)	NA	NA
psi(z_shrub)	NA	NA
psi(Z_slope)	3.087184	1.619122
psi(z_tree)	NA	NA

Wild pig (wp)

a.

Model	AIC	Delta value	AICwt
~1 ~ Z_set_area	630.2562	0	0.152145
~1 ~ Z_set_area + Z_agr_area	631.1566	0.900397	0.096993
~1 ~ Z_set_area + Z_agr_area + Z_dem	631.7185	1.462346	0.073234
~1 ~ Z_dem + Z_slope	632.1319	1.875767	0.059558

b.

Covariates	$\beta$	SE
p(Int)	-2.03072	0.137878
psi(Int)	-0.65516	0.235793
psi(Z_agr_area)	NA	NA
psi(z_cc)	NA	NA
psi(Z_dem)	NA	NA
psi(Z_dist_agri)	NA	NA
psi(Z_dist_sett)	NA	NA
psi(z_dom)	NA	NA
psi(z_gherb)	NA	NA
psi(z_human)	NA	NA
psi(Z_set_area)	0.481764	0.239323
psi(z_shrub)	NA	NA
psi(Z_slope)	NA	NA
psi(z_tree)	NA	NA

Himalayan palm civet

a.

Model	AIC	Delta value	AICwt
~1 ~ Z_dem	291.2653	0	0.184348
~1 ~ Z_dist_sett	291.8599	0.594524	0.136943
~1 ~ 1	292.4808	1.215455	0.100394
~1 ~ Z_agr_area	292.7598	1.494499	0.08732
~1 ~ Z_dist_agri	292.978	1.712612	0.078298

Model	AIC	Delta value	AICwt
~1 ~ z_dom	292.9955	1.730113	0.077616
~1 ~ Z_dem + z_cc	293.1912	1.925851	0.07038

b.

Covariates	$\beta$	SE
p(Int)	-2.23766	0.224509
psi(Int)	-1.75723	0.32477
psi(Z_agr_area)	NA	NA
psi(z_cc)	NA	NA
psi(Z_dem)	0.502135	0.286174
psi(Z_dist_agri)	NA	NA
psi(Z_dist_sett)	NA	NA
psi(z_dom)	NA	NA
psi(z_gherb)	NA	NA
psi(z_human)	NA	NA
psi(z_shrub)	NA	NA
psi(z_wild)	NA	NA

Jungle cat

a.

Model	AIC	Delta value	AICwt
~1 ~ Z_dist_sett + Z_dist_agri + Z_set_area + z_human + z_dom	197.5903	0	0.418112
~1 ~ Z_dist_sett + Z_dist_agri + Z_set_area + z_human + Z_dem	197.9575	0.367167	0.347987
~1 ~ Z_dist_sett + Z_dist_agri + Z_set_area + z_human + Z_dem + z_dom	199.5089	1.918595	0.160204

b.

Covariates	$\beta$	SE
p(Int)	-1.82464	0.243071
psi(Int)	-4.5358	1.418093
psi(Z_dem)	NA	NA
psi(Z_dist_agri)	-4.50808	1.998562
psi(Z_dist_sett)	0.394838	0.781366

Covariates	$\beta$	SE
psi(z_dom)	0.312367	0.419498
psi(z_human)	1.099276	0.484231
psi(Z_set_area)	-1.1198	0.548969

### Leopard cat

a.

Model	AIC	Delta value	AICwt
~1 ~ Z_dem + Z_dist_sett + Z_dist_agri + z_human + Z_agr_area	311.1028	0	0.462021

b.

Covariates	$\beta$	SE
p(Int)	-3.62737	0.179261
psi(Int)	34.34483	34.92585
psi(Z_agr_area)	71.73614	67.79348
psi(z_cc)	NA	NA
psi(Z_dem)	72.44906	70.32878
psi(Z_dist_agri)	-87.3828	82.26615
psi(Z_dist_sett)	167.0572	157.1399
psi(z_dom)	NA	NA
psi(z_gherb)	NA	NA
psi(z_human)	29.72971	32.8344
psi(Z_set_area)	NA	NA
psi(z_shrub)	NA	NA
psi(Z_slope)	NA	NA
psi(z_tree)	NA	NA

### Red fox

a.

Model	AIC	Delta value	AICwt
~1 ~ Z_dist_agri + Z_agr_area	243.9076	0	0.085748
~1 ~ Z_agr_area	244.5677	0.660042	0.061645
~1 ~ 1	245.0923	1.184664	0.047422
~1 ~ Z_dem + Z_dist_sett + Z_dist_agri + Z_set_area + z_shrub + z_human + z_cc + z_dom + Z_slope +	245.401	1.493371	0.040639

Model	AIC	Delta value	AICwt
Z_agr_area			
~1 ~ Z_dist_agri + Z_agr_area + z_shrub	245.4057	1.498056	0.040544
~1 ~ Z_dist_sett + Z_dist_agri + Z_set_area + z_human + Z_dem + z_dom	245.4325	1.524885	0.040004
~1 ~ Z_dist_agri + Z_agr_area + Z_dist_sett	245.8036	1.895995	0.033229

b.

Covariates	$\beta$	SE
p(Int)	- 2.08895	0.239212
psi(Int)	- 2.32724	0.467326
psi(Z_agr_area)	- 1.43356	0.868581
psi(z_cc)	NA	NA
psi(Z_dem)	NA	NA
psi(Z_dist_agri)	- 0.72508	0.507744
psi(Z_dist_sett)	NA	NA
psi(z_dom)	NA	NA
psi(z_gherb)	NA	NA
psi(z_human)	NA	NA
psi(Z_set_area)	NA	NA
psi(z_shrub)	NA	NA
psi(Z_slope)	NA	NA
psi(z_tree)	NA	NA
psi(z_wild)	NA	NA

Yellow throated marten

a.

Model	AIC	Delta value	AICwt
~1 ~ Z_agr_area	216.5855	0	0.171851
~1 ~ 1	217.803	1.217517	0.093491
~1 ~ z_human	218.2217	1.636229	0.075831
~1 ~ Z_dist_agri + Z_agr_area	218.5523	1.966792	0.064279

b.

Covariates	$\beta$	SE
p(Int)	-2.71863	0.326953
psi(Int)	-1.66914	0.39598
psi(Z_agr_area)	0.495764	0.281301
psi(z_cc)	NA	NA
psi(Z_dem)	NA	NA
psi(Z_dist_agri)	NA	NA
psi(Z_dist_sett)	NA	NA
psi(z_dom)	NA	NA
psi(z_gherb)	NA	NA
psi(z_human)	NA	NA
psi(Z_set_area)	NA	NA
psi(z_shrub)	NA	NA
psi(Z_slope)	NA	NA
psi(z_tree)	NA	NA

Porcupine

a.

Model	AIC	Delta value	AICwt
~1 ~ Z_dist_sett + Z_dist_agri + Z_set_area + z_human + z_dom	197.5903	0	0.451349
~1 ~ Z_dist_sett + Z_dist_agri + Z_set_area + z_human + Z dem	197.9575	0.367167	0.37565
~1 ~ Z_dist_sett + Z_dist_agri + Z_set_area + z_human + Z dem + z_dom	199.5089	1.918595	0.17294

b.

Covariates	$\beta$	SE
p(Int)	-1.82464	0.243071
psi(Int)	-4.5358	1.418093
psi(Z_dem)	NA	NA
psi(Z_dist_agri)	-4.50808	1.998562
psi(Z_dist_sett)	0.394838	0.781366
psi(z_dom)	0.312367	0.419498
psi(z_human)	1.099276	0.484231
psi(Z_set_area)	-1.1198	0.548969

Leopard

a.

Model	AIC	Delta value	AICwt
~1 ~ Z_dist_agri	364.7145535	0	0.049856647
~1 ~ z_cc	364.7188908	0.004337222	0.049748644
~1 ~ Z_set_area	365.5539223	0.839368727	0.032768493
~1 ~ Z_dist_agri + Z_agr_area	365.7537402	1.039186692	0.029652857
~1 ~ Z_slope	366.5405844	1.826030838	0.020008084

b.

Covariates	$\beta$	SE
pInt	-2.3545	0.213897
Int	- 1.18351	0.291168
Z_agr_area	NA	NA
z_cc	NA	NA
Z_dem	NA	NA
Z_dist_agri	- 0.46683	0.303696
Z_dist_sett	NA	NA
z_dom	NA	NA
z_gherb	NA	NA
z_human	NA	NA
Z_set_area	NA	NA
z_shrub	NA	NA
Z_slope	NA	NA
z_tree	NA	NA
z_wild	NA	NA

#### Appendix 4: Interesting findings

Camera trap photo of a leopard that most probably got entangled in a snare villagers/residents place for trapping crop-raiding animals like wild pig or for meat.

This leopard was captured in March and recaptured in April that makes us sure it has probably survived the wound.

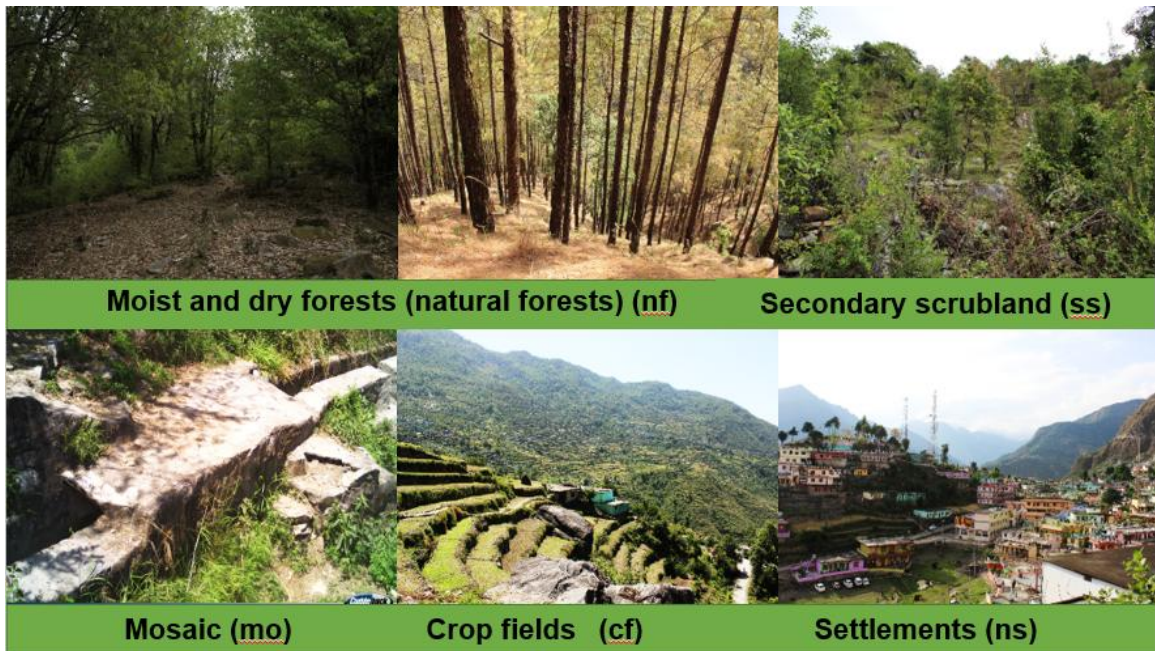


Camera trap photo of wild pig and sambar exploiting crop fields together.

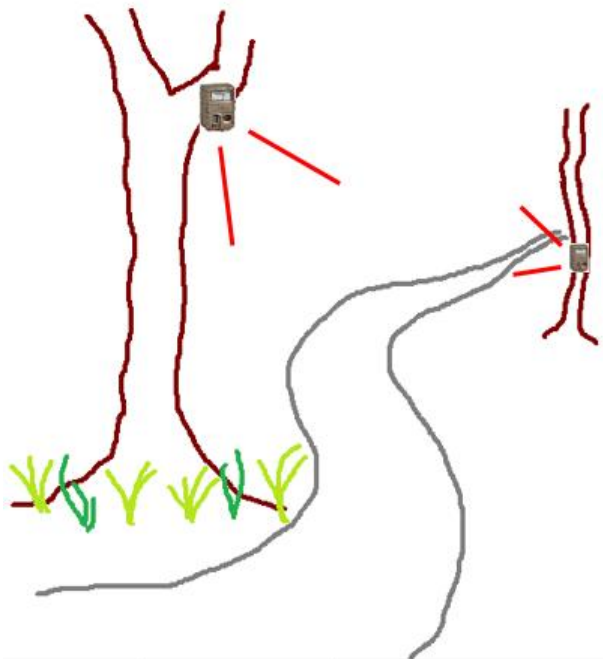


## Appendix 5: Field methods

### Categorized habitat types in study area



Strategic camera trap placement on tree branches to avoid vandalism by humans and some placed following conventional camera trap placement methodology where human presence was low.



Habitat sampling done to assess habitat covariates.



Interviews done for peoples' perception

